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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

A Junior shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

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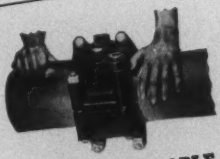

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MUNICIPAL WATER CHARGES TO INDUSTRIAL USERS

BY ARTHUR C. KING*

[*Read September 26, 1941.*]

The idea from which this short paper grew came from the wide variation in water rates for manufacturing use in different localities, noted during a study of a request for a special rate. Analysis and comparison of the published rates of twenty-six cities, towns, and water companies in New England disclosed nearly as many different rates, and many different points of change from higher to lower rates.

For ease of comparison, rates have been translated, as necessary, into charges in cents per 100 cu. ft. and step-rate quantities have been adjusted to the monthly basis, though billing is quarterly in many places. In some cases, finally, the first or high rates per 100 cu. ft. have been taken from the maximum amount covered by the minimum charge.

Users of water and manufacturers of fixtures and equipment usually think and speak of quantities of water in gallons, although cubic feet are more commonly used in New England for making up charges for water. In this comparison, it seemed advisable to set a figure such as might be needed by a moderately large user. That figure has been taken, in the words of the customer, as 100,000 g.p.d., or for a working-day month of 25 days, as 333,333 cu. ft. per month. In comparing the point of change in rates, a month of 31 days has been used in those cases where the rate changes are based on the average quantities used per day.

The most common number of rates in use seems to be three, as no less than 10 of the 26 communities listed in the accompanying table use only three different regular rates, although Fall River uses 14. First or high rates vary from New Haven's 50¢ for the first 200 cu. ft., to Manchester's 10¢ for the first 33,333 cu. ft. Holyoke's single rate of 4¼¢ for any quantity should be mentioned, as well

*Superintendent and Clerk of the Board, Water Works, Taunton, Mass.

MUNICIPAL WATER CHARGES TO INDUSTRIAL USERS

LOCALITY	Monthly charge for 333,333 cu. ft.	Gravity (G) or Pumped (P) Supply	Number of Rates	First Rate in cents per 100 cu. ft.	Point of change to 2nd Rate—cu. ft.	Lowest Rate in Cents per 100 cu. ft.	Point of cu. ft. change to Lowest Rate—
Augusta, Me.	$208.	G & P	7	20	333	6	33,333
Ayer, Mass.	379.	—	3	41½	222	11¼	1,111
Brattleboro, Vt.	240.	G	3	30	5,000	10	10,000
Bridgeport, Conn.	280.	G	4	15	6,667	6	40,000
Burlington, Vt.	348.	P	3	20	10,000	10	20,000
Concord, N. H.	200.	G & P	10	16 2/3	500	7	145,000
Fall River, Mass.	396.	P	14	24	775	10½	217,000
Fitchburg, Mass.	141.	G	3	18	1,667	4	18,333
Hartford, Conn.	307.	G	2	15	93,000	7½	93,000
Holyoke, Mass.	142.	G	1	4¼	—	4¼	—
Lynn, Mass.	405.	—	3	15	16,667	8	416,667
Manchester, N. H.	197.	P	3	10	33,333	5	100,000
Middleboro, Mass.	511.	P	7	19	40,000	10	1,000,000
New Bedford, Mass.	259.	P	5	11¼	3,300	1	666,600
New Haven, Conn.	390.	G	7	50	200	5	750,000
Norwich, Conn.	211.	G	3	25	1,667	6	16,667
Peabody, Mass.	490.	—	2	15	300,000	12	300,000
Pittsfield, Mass.	202.	G	3	12	1,667	6	5,000
Portland, Maine	248.	G & P	4	14	10,000	7	30,000
Providence, R. I.	267.	G	3	18	3,333	7½	33,333
Salem, Mass.	500.	—	1	15	—	15	—
Springfield, Mass.	167.	G	2	22	1,667	5	1,667
Taunton, Mass.	239.	P	3	19	3,333	6¾	33,333
Westerly, R. I.	300.	P	6	22½	2,060	7½	124,000
Woonsocket, R. I.	244.	G & P	4	21	3,333	7	10,000
Worcester, Mass.	300.	G	1	9	—	9	—
AVERAGE	291.		4	19 1/3	23,423	7½	176,741

as Worcester's special rate of 9¢ for all exclusively manufacturing use. The most common first rate among those listed is 15¢, which prevails in 5 places.

Low rates for quantity use vary from the Salem, Mass., single rate of 15¢ down to New Bedford's 1¢ for quantities over 666,600 cu. ft. per month. In Ayer the low rate of 11¼¢ is applied for use of over 1,111 cu. ft., while in New Haven the low rate of 5¢ is not applied until the use reaches 750,000 cu. ft. The most common low rate is 6¢, used in four places, closely followed by 5¢, 7¢, 7½¢ and 10¢, each used in three places.

Brattleboro, Vt., Concord, N. H., Peabody, Mass., Portland, Me., and Springfield and Worcester, Mass., have special rates for exceptionally large users or for strictly manufacturing use. Springfield, which supplies several communities as well as some very large manufacturing plants, enters into individual contracts in such cases.

In Bridgeport, Conn., the charge is made up of a fixed charge, based on the size of the meter, in addition to the charge for water, and in New Bedford there is a yearly meter rental of 10% of the cost of the meter.

There is no apparent consistent relation between rates and methods of supply, that is whether supplied by gravity or by pumping. To be sure, most of the lowest rates occur in connection with gravity supplies, but some rates below the average are found where the supply is pumped, and some of the gravity systems have rates above the average.

Many factors enter into the establishment of proper rates for each individual system, in addition to the one already mentioned: method of supply. First cost, affected heavily by geographic and other local conditions, as well as operating cost, varies much even in the small area of New England and is reflected in the rates. No schedule can, therefore, be picked as the one correct solution for all, but it is hoped that this synopsis may be of interest by way of showing us what "the other fellow" does in this respect.

FINANCING WATER MAINS

BY WILLIAM P. MELLEY*

[*Read September 26, 1941.*]

Finding money with which to extend or replace water mains is a problem that all growing water works, either publicly or privately owned, face continually. Although there are well-established sources for the funds, the choice may be improperly dictated by community habits already well formed, by certain conditions peculiar to the locality, or by politics.

The principal sources for funds are bond issues, departmental revenue from surplus or reserves, appropriation from general tax levy, contributions (in whole or part) by developers, and assessments against abutting property.

The issuing of bonds is a popular means for raising money. It defers payment of the cost of work done with the money, so that future property owners or water takers, who will benefit from the improvements, so financed, will pay for some of the expense incurred, either in their real estate tax bills or water rates. Paying off the principal and interest may be handled in several ways, but the most common practice is to pay the retirement charges out of real estate tax and the interest from water department revenue.

To use surplus or reserves for installation of mains is to spend money set aside for that purpose out of earnings of previous years.

The municipality may contribute all or part of the cost of extensions of mains by appropriating funds for that purpose from the real estate tax levy.

In the four sources already noted, the money comes either originally or finally from the owner of real estate or from the water taker. When a developer of a property contributes a part or all of the cost of an installation, or all or part of the cost is assessed as a betterment against the abuttors, it may be considered that those chiefly benefited are supporting the improvement.

*Superintendent, Water Department, Milton, Mass.

Proper public water works operation consists principally in supplying potable water for domestic, commercial, and industrial use. A secondary but very important obligation is to insure an adequate supply of water, not necessarily pure, for assistance in fire fighting. It is not necessary to combine these two functions in one system, but, because of the heavy investment required, they are almost universally performed by the same mains.

The first service places a more or less uniform demand on the water works for pure, tasteless, colorless water, and because of the steadiness of demand, does not require large distribution mains and equipment such as are needed for fire fighting, when considerable quantities of water are drawn for relatively short periods.

We have all experienced the need of replacing small pipes, two, four or six inches in diameter, with larger pipes when the smaller sizes were adequate for domestic supplies. It would seem that there should be some distinction between the sources of funds for financing the cost of mains for domestic use and those used principally for fire fighting.

Most authorities distinguish between the functions of a publicly owned utility such as a water department and other municipally operated departments such as sewer, fire, police, and highway departments. Actually a municipally-operated water works provides within its customary functions, the two distinguishable activities. In cities that have two water systems, one distributing potable water and another carrying water solely for fire fighting, the latter is paid for entirely out of the general tax levy, *i.e.*, assessed wholly against real estate. This appears reasonable because it furnishes water for the protection of real estate. If the reasoning behind this is just, it would seem logical to state that the cost of mains in sizes greater than those adequate for domestic use should, in some manner, be supported by a charge against real estate. The dual functions of a water department have resulted in the confusion of practice as to the proper pocket to dip into to finance extensions.

Municipally-operated water works are owned by the taxpayers, but financial set-ups many times place an unfair burden on the water taker. Many works were originated as private companies by citizens who were far-sighted enough to realize the need of a community enter-

prise to supply water for domestic and industrial purposes and for fire protection. Later, when the city or town acquired ownership of the plant, bonds were issued in payment to the stockholders of the company. It has been considered good practice that the cost of redeeming the bonds be paid from the proceeds of the real estate tax, *i.e.*, by the taxpayer, while the interest on them often comes from water department revenue or the water taker. It is the opinion of many concerned with the water works rate-making that, general practice to the contrary, that part of a water system which provides water for fighting fires should be financed in its first cost and perhaps its maintenance by assessment against the property it protects and not by water takers.

How to separate the cost fairly between real estate owner and water taker is the problem. In some cities and towns any surplus water revenue is placed in the general funds and is spent for other municipal needs, such as road building and sewer construction. In others any water deficit is made up out of the general tax levy. These practices are unfair, because in the first case the water taker pays in his rates for some separate municipal function; while in the latter case, the rates are not sufficiently high to support the service for which the consumer pays.

A water department should be self-supporting, and its surplus revenue should be reserved for water department uses. Only in this way can there be assurance that the water taker, in the rates he pays, supports completely and only the department which supplies him with water.

However, as mentioned before, a part of the function of water works is to supply water for fire fighting, and the support of this part of the plant is one that should be borne by the owner of real estate rather than the water consumer. Recognition of this fact is taken by municipalities and in several different ways: (1) a charge for hydrant rental; (2) a charge based on the pipe mileage; and (3) the so-called "inch-foot" charge.

Simple hydrant rental is by far the most commonly used, and it would seem that if any change were made from that method with the idea of recognizing the fairness of a contribution to water works by the real estate tax payer, the second plan might be skipped in favor of

the inch-foot basis. The last mentioned method is probably the fairest, because it credits the large mains that are needed for fire fighting in some districts.

With the idea of learning something about the general practice followed in this section of the country questionnaires were mailed to a number of cities and towns in New England including both municipally and privately operated plants. The questionnaires returned indicate widespread differences in policy.

There was an even division as to whether there should be any distinction regarding means of financing improvements to the system and installations in new developments. In most cases where the city or town is not undergoing rapid growth, mains appear to be financed from income, but bond issues are the popular means of obtaining funds for this work. In three instances, developers share the expense of new mains. In one case, half of the cost and in another three-fourths of the cost (both based on an eight-inch main) are paid by the real estate developer. A charge of $1.00 per front foot is made in the third instance.

Under the guarantee plan, which is most commonly used, a water works requires revenue from an installation, rather than a contribution toward the capital cost. The income expected varies from 4% to 10% for periods ranging from five to ten years. In only two of the towns heard from was any deposit required that would guarantee the necessary income. In one town guarantees are not expected for accepted roads. Private companies seem willing to extend a main 100 ft. for each new customer and enforce the guarantee plan for longer distances. Although cities and towns are paying bond interest of about one-third the rates existing ten years ago, no reductions have been made in revenue required under the guarantee plan.

It is interesting to note that with two exceptions all departments were satisfied with their present methods. Each city or town has its individual problem and its own method of meeting it. It is not easy, and perhaps, in my opinion, not correct, to set up one made-to-measure plan that will fit every case. For example, in Milton, Mass., with a population of 20,000, 95 miles of main, and 5,200 services, for the past 17 years most of our extensions have been financed by selling bonds, although in many years sums varying up to $50,000

have been contributed from revenue or surplus, when such sums were available. During this period, which was initiated by a vote of the town putting its water department on a strictly self-supporting basis, both the bond interest and retirement have been paid by the Department from its funds.

This placed a rather heavy burden on our dollar resources and it was necessary to provide additional sources of revenue, particularly because, due to rapid growth of the town in localities that were not well-supported with large mains, a heavy program of reinforcements and improvements was inaugurated, in addition to extensions in new developments.

The reinforcing installations that produce no revenue, were made almost entirely for increasing the quantity of water available for firefighting and prevented a sizeable increase in fire insurance premiums. Milton, being almost completely residential, had sufficient water for domestic needs, but the supply was inadequate to meet the requirements of modern fire demands. It was, therefore, apparent that the expense of financing the improvements should be borne principally by the taxpayer, rather than the water taker. By agreement, then, the town agreed to raise in its general tax levy a sum sufficient to contribute to water department funds annually, $35 per hydrant, which would pay the greater part of the carrying charges of bonds issued to finance the new mains. By this means, the real estate tax bears its share of the burden.

To further relieve the water taker, the Commissioners changed the method of billing for service connections that are made by the Department employees. Now the entire cost of a service, from main to meter is billed at cost plus 25% and the cost of the meter is added. This was rather humorously called, by one of the Water Commissioners, "newcomer's initiation fee as a Milton resident."

As most new services are in newly-developed property, the Board feels it is sufficiently recompensed by requiring a return of 6% for 6 years on the actual cost of installation of mains on a basis of a 6-in. pipe. A cash deposit of one-third the cost is made in a local savings bank to the order of the Department.

Our records in Milton show that in the 40 most recent installations made in new developments, one-third returned the required

income at the end of the first year, two-thirds were satisfying our demands at the end of two years, and at the end of three years 85% were producing sufficient revenue.

We are not satisfied that this is being handled correctly in Milton, but we do believe that through the charges for hydrant rental and service installation the owner of real estate and the developer are sharing in the cost of mains laid to improve fire protection and in the financing of mains extended into new developments.

Some day, legislation may provide for: taxation of water works plant; setting up depreciation reserves; charges in the general tax levy for that part of plant required for fire protection; and assessment against abutting property as a betterment of mains laid in new developments. But until some or all of these idealistic measures are made into law we must use the tools we have in the way we know best to use them for our individual needs.

Discussion

William W. Brush.* You may be interested in what New York does. We have the 100-ft. basis for extensions for one family, the length needed to cross a street intersection not being included. No money is put up by the property owner. The main is paid for by money secured through a bond issue. Beyond the distance to which the city will extend the main at the city's cost, the pipe becomes a private extension paid for by the owner. The private portion of the line is made of whatever size the owner desires but the work is done under Department inspection. Usually a small pipe, 2-in. or smaller, is laid.

New York City has the additional revenue from an increase in the assessment on lots after a main is installed in front of such lots. This tax revenue does not come to the Water Department but pays for quite a considerable portion of the extension. I believe that the municipality is rather naturally inclined to carry on this work without expecting an adequate direct return on the cost of the extension.

Private companies have a much sounder policy in making extensions, because an adequate return must be secured in fairness to the customers and stock holders. I would much rather be in the position

*Editor, *Water Works Engineering*, New York, N. Y.

of the private company. On the other hand, I do believe that the majority of the municipal systems are not really doing anything unfair. They may put a little greater burden on the old water consumer, but it is not very serious and balances up fairly well.

In New York, no taxes are paid on the water property within the city limits, and the city pays nothing for the hydrants. When I was in the New York Department, there were about 75,000 hydrants, and assuming thirty dollars a hydrant as a fair annual charge for fire protection, the annual rental would be about $2,500,000. The annual tax on the water property in the city limits would be certainly around $2,000,000 or $3,000,000 so that there would be a pretty fair offset one against the other.

I am inclined to think that it would be very desirable to have set up clearly, what is an equitable method of handling extensions for municipally owned water plants. The probabilities are that very few of the communities would change from what they have been doing, because, after all, the consumers in the past years have been served on the basis of what is the practice, and to change it is likely to create as much unfairness, or more, than to continue the existing practice.

I have been rather inclined to the view that a 6-in. main is pretty large for domestic service. After all, the consumer theoretically should pay only for domestic service. If he is a property owner, he should be paying for fire protection separately. Actually, he may be paying either more or less than he should, but nevertheless I believe that basically all that the consumer should pay for is the size pipe required for domestic service.

In dealing with private water companies operating in New York City, we have taken as the basis for determining the amount to be paid for fire hydrant rental, the difference in cost between the water system as installed and the system that would be required to give only adequate domestic service and provide capacity for domestic service for a five-year period beyond the time under consideration. Then the cost for the remaining part of the system that is useful and used for fire protection is chargeable to fire protection.

Upon that basis, we compute the interest, depreciation, maintenance, and operation charges to be allowed for fire protection, and, in that way determine the hydrant rental. It seems to me that a 6-in.

pipe is a rather liberal size when one is determining what the consumer as such should pay. There is such a close intertwining of fire protection and the domestic supply that I think the 6-in main has become so generally used that perhaps we should not quarrel with its use as a size for domestic use.

DONALD C. CALDERWOOD.* Speaking for a private company, we are subject to the control of the Public Service Commission of the State of New Hampshire, and the rule under which we operate allows us to extend our distribution system 100 ft. to meet each new customer without any extension charge. For example, if there were three customers on a new extension 500 ft. long, the total allowance of "free" pipe would be 300 ft., and the customers would divide equally among them an annual "investment charge of 6% based on the actual construction cost of 200 ft.,—that is, 6% of the total construction cost after an allowance of 100 ft. per customer is made. This "investment charge" exists for five years and is in addition to the regular scheduled rates. Subsequently, should another customer connect to this particular extension, the investment charge would be recomputed making an allowance of 100 ft. of pipe for the new customer and dividing the remaining "investment charge" among the four customers for the remaining portion of the original five-year period.

We have a definite obligation to serve the people, and they consider that we are charging them for something they are not getting when they have to pay this investment charge. Of course we have a different viewpoint of the matter, but they figure that because they are only a few hundred feet beyond the other fellow, on the same street, and in the same ward as he they should pay the same water bill as he. They do not realize that you made the additional expenditure just for them.

Since the return of only 6% based on the construction cost is very low, we have a provision in the rules whereby, if the extension is unusually long or where the cost of construction is unusually high, we may ask the Public Service Commission to establish a new annual investment charge and a new duration of the guarantee period for that particular case. A record of all guaranteed extensions has to be filed

*Pennichuck Water Works, Nashua, N. H.

with the Public Service Commission. They will allow us to shut off or discontinue the water if the payments are not made. This carries through for the additional owners, should there be any transfer of the property during the five-year guarantee period.

I am a little surprised to hear that practically everyone bases his charge on a 6-in. main, particularly where fire protection is concerned. I thought that in these days of thousand-gallon pumpers the National Board of Fire Underwriters and other inspection bureaus would not approve of mains less than 8 in. in diameter. With few exceptions, we have used nothing smaller than 8-in. pipe for the last eight to ten years.

After all, the difference between the installed cost of 6-in. and 8-in. mains is not great. It just so happened that in most of the extensions that we have recently made, the fire commissioners have seen fit to order a hydrant placed either at the end of, or near the end of, the extension. The customer in each instance gets the benefit of the rental from the hydrant, and it has worked out to his advantage to have the hydrant on the extension not only from the standpoint of the insurance rate but also from a financial standpoint of reducing his annual investment charge.

THEODORE L. BRISTOL.* I represent a private Water Company in Connecticut. Fire protection is paid for by the City at the rate of 9.2 mills per inch-foot and $10.00 per hydrant per year. By inch-foot is meant the product of the length of main in feet and its diameter in inches, *e.g.*, a 6-in. main has 6 inch-feet per foot. It is our opinion that nothing less than a 6-in. main should be installed. An 8-in. main for fire protection is preferable in most situations as a minimum.

Our extensions are based on a 10% return per annum for a period of 20 years on the cost. Whatever the city pays us for fire protection per year is taken out of the 10% and the balance charged to the subscribers. We base our charges on the cost of a 6-in. main and put in larger pipe if we think it may be required.

F. R. Berry, Engineer, American Water Works and Electric Co., New York, has an article in the Journal of the A.W.W.A., Vol. 33, p. 1041 (1941), in which he states that a return of 25% is necessary.

*Ansonia, Conn.

He also gives the rules adopted by the regulating bodies of the states of New Jersey and New York. L. A. Jackson, Manager, Municipal Water Works, Little Rock, Ark., has papers published in the Journal of the A.W.W.A., Vol. 30, p. 1 (1938) and Vol. 33 p. 1357 (1941), on "Financing Water Main Extensions," which are worth reading.

My own idea about returns is that one should get the average of the gross revenue received divided by fixed capital, plus say 5% for the hazard of a new extension and the fact that the average, in cases where water is sold to industry at low rates, would be too low for residential extensions, *e.g.*, if a gross revenue of $150,000 is divided by a fixed capital of say $1,000,000, the average would be 15%, to which 5% should be added for the hazard, etc., which would make a return required of 20%.

GEORGE C. BREHM.* I don't know whether you recall that back in 1927 an act was introduced through the New England Water Works Association for the betterment of water mains. We got along very well with the Committee on Municipal Finance, but Mr. Waddell's office did not seem to favor betterment assessments in any form. He is very much opposed to betterments of all kinds, because they have been, in a great many cases, abused. I was chairman of that committee, and we just couldn't get to first base on betterments. Personally I think that the betterment assessment is the way to do it. I recall that when I was a city engineer, some person at the end of a street might possibly want 1000 or 1500 ft. of main extension and was willing to sign up a guaranty. We would go ahead and put in the water main. The houses would be very much scattered on the street; there might be three or four houses in a thousand feet. Persons owning vacant lots would sit back, and the minute the water main was in they would start building and selling lots. It is my opinion that the betterment assessment is the proper and fair way to collect for the improvement of the property that comes with the installation of a water main.

In reference to fire protection, we had in Amherst a 3-in. main that came down from an original old spring-water line, laid in 1860, and fed about thirty families very satisfactorily so far as domestic supply was concerned. We had some fire-flow tests made three or four

*Amherst, Mass.

years ago, and we found out that we did not have enough water down in the center of the town so that we had to relay a little over a mile of that 3-in. pipe with 12-in. pipe, purely for fire protection purposes. I agree with Mr. Melley, therefore, when he says that there certainly is a very definite charge for fire protection that should be paid for as such in some form.

J. E. GIBSON.* If you analyze your capital investments you can classify them under two heads: distribution system and water supply. The latter, of course, includes the cost of obtaining water. The distribution system includes supply mains, distribution mains, valves, hydrants, etc. You will find that there is some relationship between the cost of the water supply system and the distribution system. This ratio may run as low as 25 per cent for the distribution system to 75 per cent for the water supply. That is to say, as a minimum, the distribution system capitalization amounts to about 25 per cent of the total and the water supply will run as high as 75 per cent of the total; therefore it will be seen that for every dollar invested in distribution system there must be a further sum of money, amounting in extreme cases to as much at $3, invested for water supply, pumping equipment, etc. If you figure that 6 per cent is the minimum return you must obtain on the distribution system, then you must obtain an additional 6 per cent on another $3 invested in the water supply end of the plant, or a total of 24 per cent required to meet actual expenses on the dollar invested in the distribution system. This may not be immediate but it will have to be met ultimately, and there is no virtue in deceiving ourselves. I think 25 per cent and 75 per cent possibly an extreme case. At Charleston we are located on the coastal plain, and salt water contamination extends back a number of miles from the coast line. Therefore, to obtain an adequate water supply it is necessary to go a long distance to get above salt water contamination; or to dam a salt water stream and allow the storage basin formed thereby to freshen from the inflow. In any case, the development of a water supply is an expensive undertaking, so we figure that the cost of obtaining a satisfactory water supply, together with a treating plant, pumping station, etc., runs about three times the cost of an ordinary

*Charleston, S. C.

distribution system. We have therefore capitalized our money expended in the distribution system at 25 per cent, or in other words, we require a return of four to one.

Our procedure with the real estate promoters is to require that they pay for the total cost of the mains, valves, and hydrants, on 6-in. size main. Our Commission assumes all cost in excess of 6-in. size main, and maintains the lines laid under these contracts in perpetuity. They reserve the right to enlarge and extend the mains laid under these contracts without in any way vitiating the contract. Then for each service that is connected to these mains for water supply we return a certain sum of money, based upon the size of the tap made. These returns are as follows:

Size of Service—In.	*Return*
¾	$ 40.00
1	70.00
1½	170.00
2	350.00

This return is based upon the minimum annual guarantee made the department for the respective sized services, and of course should the consumer use more water than the minimum allowed, the water department stands to earn a little bit larger return; but usually this is not the case, as most of these developments are made for residential purposes and our rates are such that the ordinary family has sufficient water under our minimum allowance.

If a municipal or political subdivision contracts for hydrants then we made the real estate development a further return, amounting to approximately $85.00 for each hydrant connected.

These contracts run for a period of 15 years but refund is made only once for each tap connected and only then when the department is reasonably assured of a continuing consumer of water.

CHAIRMAN ESTY. Do you know offhand what the difference in construction cost might be between materials at Charleston and costs in New England, where we have to go down 5 or 6 ft.; I suppose you use very shallow ditches.

MR. GIBSON. Our costs for materials, so far as construction is

concerned, I think will run very close to what you pay for materials in New England. For instance, 6-in. cast-iron cement-lined pipe today is bringing somewhere in the neighborhood of about 90 cents a foot. In Charleston area we have no rock, it is sandy soil, and our worst enemy is ground water. Where we lay 6-in. pipe, the labor cost is somewhere in the neighborhood of about 16 cents a foot, based upon a 30-in. cover, or 3-ft. depth of trench. We use very little sheeting. But occasionally we have to go deeper to avoid sewers and other subsurface constructions. Here the cost jumps rapidly due to ground water conditions and running sand. The price of 16 cents per foot is based on what is locally known as task work—that is to say, we pay at the present time 30c per hour for labor, working nine hours per day. We will guarantee to the laborer a full day's wage of $2.70, but if for any reason the gang will exceed what we consider a reasonable day's work we pay them a bonus based upon the total number of feet of pipe laid. If these men are expert diggers they can readily earn about $3.60 per day, or 40 cents per hour, and we have had gangs that would do much better than this. There is one other particular advantage in this method of pipe laying and that is, that if you have an efficient gang of men and a slacker develops in the crowd, the other men will run him off the job and you do not have to fire him. In other words, if they are all willing to put out they can earn a good bonus and generally they do.

Before we extend a main, we make a contract, and we don't put a spade in the ground until the money is on the barrel head. Now, if the extension costs less than our estimate we return the difference immediately. The contract runs for a period of fifteen years. If enough water consumers are connected during the first year of development then the real estate developer will get the entire cost of the development back immediately; however, if an insufficient number of customers is obtained during the period of the contract, fifteen years, he is just out of luck. However what the real estate promoter does is to first purchase the land, make division into lots, and come to the water department and ask for an estimate of the cost of water mains to supply the development. He usually wants to be sure that our estimates are correct as he expects to add the cost of the extension to the property and then divide it by the number of lots available, so in reality the real estate promoter includes the price of water supply in

the price of his lot, and then when the lot owner signs up for water and becomes a customer of the water department, the promoter gets a further return, which may, if he is lucky, amount to double the cost of the water supply system.

FRANK GIFFORD. Has anybody had any experience with legitimate takers—by that I mean people who have been outside of the system a number of years, perhaps on wells, and twenty or thirty of them now want water?

MR. GIBSON. Well, a number of people on a street will get together and agree to sign up a regular form of contract for water. We are willing to expend $40 for each customer to lay the main; however should the cost of the extension exceed this amount, then we ask the customers to put up sufficient money to make up the difference, *i.e.*, if there are 10 parties involved and the cost of the main is only $400, then they do not have to put up anything. However, if the cost of the main is $500, they each have to put up $10, and this is not returned to them unless there are vacant lots within the limits and people in the future join, when we return to each original depositer a prorated amount, or in the case of ten, $4 each, until such time as he gets all of his money back and this must occur within a period of fifteen years. This however, does not include any service cost and each individual customer pays for his own service from the main to the property line, and the water department maintains this service in perpetuity.

I think we have in force some fifty contracts under this form of agreement, and I think about one-third of them have been paid out in less than five years. Another third have got their money back in from ten to twelve years. That leaves about one-third who will never get their money back.

LELAND G. CARLTON.* For many years the City of Springfield has made all of its main extensions on the guaranteed revenue basis, the only exceptions being three WPA projects that were recently completed, and some extensions that had to be made for the improvement of the distribution system. Formerly the petitioner or petitioners for the extension were required to sign an agreement whereby, if the City laid the pipe, it would receive annually a revenue of $20

*Springfield, Mass.

for each one hundred feet of pipe laid. The signatures were witnessed, which made the agreement a promissory note collectable up to twenty years. The $20 rate was originally selected to provide a certain percentage of return on the cost of laying one hundred feet of 6 inch main. However, the City reserved the right to designate the size of main, without altering the amount of the guarantee. Collection of the guaranteed revenues was not always easy, so when an amendment to the water lien law which provided a possibility of changing the old form of petition for a more satisfactory one, was passed about two years ago, advantage was taken of this amendment. With the new form of petition the guaranteed revenue per one hundred feet is the same, the bills are rendered quarterly instead of annually, and a petitioner can subdivide his total guarantee, placing definite portions of it against as many lots on the extension as he owns, provided that the sum of all the portions equals the total guarantee required. The new petition also provides that the obligation assumed by the original petitioner be passed on to a new owner, and inasmuch as the obligation is placed against the property, it may become a lien if not paid. One unfortunate feature of the new petition is that it does not have to be recorded and consequently a new owner may not know that he has assumed an additional obligation. However, little trouble has been experienced in making the collections. All revenue received from services connected to an extension, whether paid by the original petitioner or by someone else, is credited to the petition for the extension, and each extension is a contract by itself and receives no benefit from any further extension.

CHAIRMAN ESTY. There is one other thing that came to my mind on the extensions. For instance, on this guaranty, you extend a pipe line 300 feet for one customer. Then somebody else wants an extension of another 100 feet. Your requirements would be three times as great for the first one as for the second. How is that handled.

MR. CARLTON. The minimum rate for a single house is $8.00 a year which would automatically guarantee for forty feet of extension, and as the minimum rate is usually exceeded, it has become customary to lay fifty feet of extension without a guaranteed revenue

petition. This amount will usually provide for an additional house on each side of the street.

CHAIRMAN ESTY. But it was through the efforts of the first one that the extension was made.

MR. CARLTON. That is true.

CHAIRMAN ESTY. But he has to pay three times as much money.

MR. CARLTON. Each one is a separate contract. Just as soon as other takers are connected to the first 300 feet the revenue received from them is applied towards the $60 guarantee, and as soon as $60 a year is received from this extension, the contract is cancelled.

It would seem as though the most equitable basis of laying a water main extension would be by the betterment method, where assessments could be made against each lot that fronted on the extension. This method was considered in Springfield some time ago. The city has the right, under a special legislative act, to assess betterments for the building of sidewalks, curbings, pavements, etc., but not for the laying of main pipe extensions. The Water Board could work under the betterment system on private streets, since it has the authority to take rights of way. However, in a public street the land already stands in the name of the city, and as the Water Works is a part of the city, no taking can be made. Consequently, a bill was introduced in the legislature, which would grant the Water Works the privilege of making all extensions on the betterment system. The bill came up for hearings with no apparent opposition. One suggestion was made that the bill become a general act rather than a special act for Springfield. This suggestion was acceptable to Springfield. However, that was the last that was ever heard of the bill.

COOPERATIVE GROUND-WATER INVESTIGATION IN MASSACHUSETTS[1]

BY M. L. BRASHEARS, JR.[2]

[*Read September 25, 1941.*]

In 1938, the U. S. Geological Survey, in coöperation with the Massachusetts Department of Public Works, began an investigation of the ground-water resources of Massachusetts. This work is a part of a larger coöperative program that also involves geologic studies and topographic mapping. The chief purpose of the ground-water investigation has been to secure detailed information concerning the occurrence and availability of ground water in the state. Such data will provide a basis for the more effective utilization of the ground-water resources of the state. The studies will doubtless indicate areas where additional ground-water developments can safely be made and other areas where present developments are already excessive. Because the funds available at the start of the investigation were relatively small, only a part of the state could be studied each year. It was planned, therefore, to continue the work from year to year until the entire state had been covered. During 1939, the appropriation for this work was reduced, and the scope of the work had to be curtailed considerably.

The field work that forms the basis of the investigation consists chiefly of an inventory of existing wells and the collection of related information pertaining to ground-water conditions. Many of the well data were obtained from statements and records of well owners, and well logs were furnished by well drillers. Measurements of ground-water levels and observations of ground-water conditions were made at the time each well was visited. Officials of public water-supply systems utilizing ground water, and private well owners, both industrial and domestic, were interviewed. In each township that was covered, most of the domestic wells and all of the wells that were known to yield considerable quantities of water were visited. The

[1]Published with the approval of the Director, U. S. Geological Survey.
[2]Assistant Geologist, U. S. Geological Survey, Jamaica, N. Y.

well records that have been collected include data pertaining to well logs, well construction, water-bearing formations, depth to bed-rock, depth of well, yield, ground-water level, etc. The location of each well was plotted on a topographic map at the time the well was visited.

In Massachusetts, as in other glaciated regions of the United States, many of the larger ground-water supplies are obtained from deposits of sand and gravel that occur in pre-glacial bedrock valleys. In some parts of the United States, these buried valleys contain several hundred feet of glacial outwash, but in Massachusetts the valley filling is commonly not so thick. In many places, the glacial outwash is highly water-bearing. The location and configuration of some of these buried valleys is not readily apparent. In order to utilize effectively the ground-water resources of such an area, the extent of the buried valleys must be determined.

In Massachusetts, a number of buried valleys are known to exist from which considerable quantities of ground water are withdrawn. At the start of the ground-water investigation it seemed desirable to begin work in one of these areas. Accordingly, field work was begun in the Lowell area in October 1938. The average withdrawal of ground-water in this area is estimated to be somewhat less than 7 m.g.d., of which more than 5 m.g.d. is for public supply. Field work was started in the Aberjona Valley area in August 1939. The average withdrawal in this area is estimated to be about 5.5 m.g.d., of which about 2 m.g.d. is for public supply. To date, field work has been done in 30 townships in these two areas, and records of about 1,000 wells have been obtained. The inventory of wells has been completed in the 14 townships shown in Figure 1.

Weekly measurements of ground-water level are being made in the Lowell and Aberjona Valley areas chiefly for the purpose of establishing the relation between ground-water levels and pumping. These observations were first made during the summer of 1939. At present, measurements are being made in 35 wells in Middlesex County and 2 wells in Worcester County. Automatic water-stage recorders are operated on three of these wells. The measurements of ground-water level are published annually in Water-Supply Papers of the Geological Survey. Records not yet published may be consulted at the office of the Geological Survey in Jamaica, New York. Figure 2 shows the average monthly ground-water level in three groups of wells in Middle-

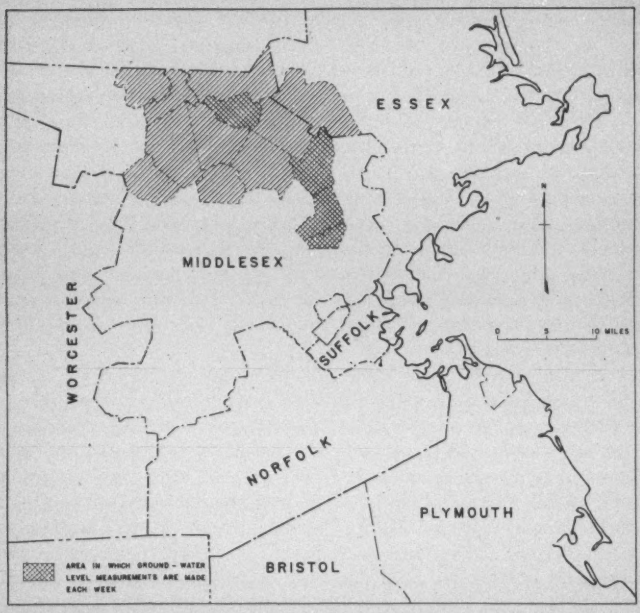

FIG. 1 INDEX MAP OF NORTHEASTERN MASSACHUSETTS SHOWING TOWNSHIPS IN WHICH WELL INVENTORY HAS BEEN COMPLETED

sex County. The monthly averages are based on measurements made near the end of each month and have been obtained by expressing measurements for each well in feet above a zero datum, arbitrarily chosen for each well. The zero datum was chosen 10 ft. below the water level in each of the wells at Lowell on November 28, 1939, and in each of the wells in Aberjona Valley on December 1, 1939. Thus, on these dates all the wells being measured at that time had a stage 10 feet above the zero datum. A number of observation wells were added to the water-level program after December 1939. When a measurement in a new well is added to the average, the water level in the new well is assigned a value equal to the average water level in all other wells in that group on that date.

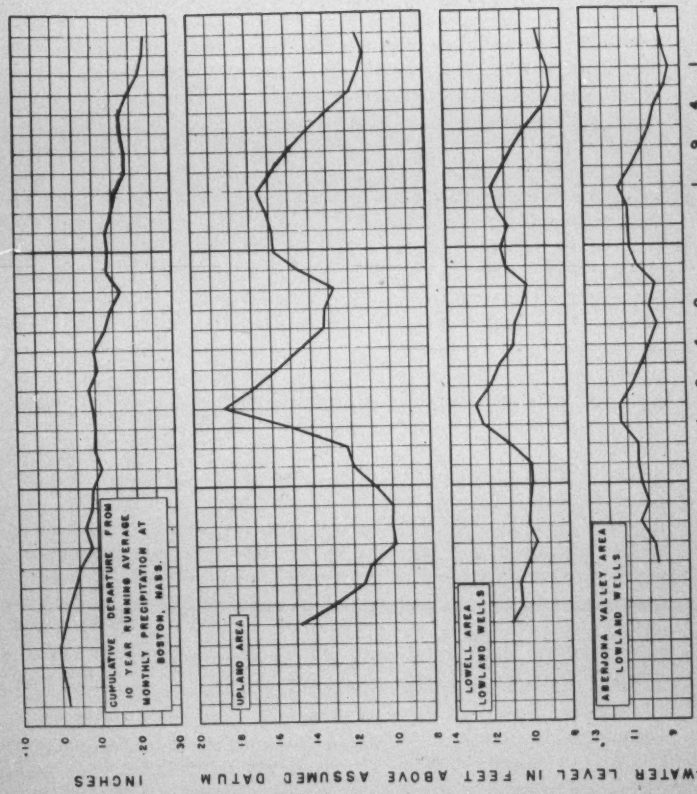

FIG. 2 AVERAGE GROUND-WATER LEVEL IN MIDDLESEX COUNTY, MASS.

For most of the period of record, the graphs of average water level for the Lowell and Aberjona Valley areas are based on measurements in 9 wells in each area. Most of these wells are screened in the heavily pumped stratified sand and gravel. At present, the graph of average water level for the upland area is based on measurements in 16 wells, of which 2 are in Lowell, 9 in the Aberjona Valley, and 5 in Wilmington. Most of these wells are in the higher parts of the region and end in more or less unstratified sandy clay. The withdrawal of ground water in the upland areas is relatively small.

The relation between average ground-water level and precipitation is shown in Figure 2. The graph of precipitation shows the cumulative departure from average monthly precipitation at Boston. The average monthly precipitation for the preceding ten years was used in determining the departures each month. The available records of water level cover too short a period to warrant definite conclusions concerning the general trend of ground-water levels. However, a comparison of the graphs indicates a general relation between the trends of precipitation and water level. It will be noted that the general trend of precipitation is downward during the period covered. This doubtless is the chief reason why the highest points on the average water-level graphs in 1941 are lower than the highest points in 1940. It will also be noted that during the fall of 1941 the average water level in the two heavily pumped areas is at the lowest stage since the start of record. Figure 2 shows that the annual range of average water level in the upland area is somewhat greater than that shown by the lowland wells in the Lowell and Aberjona Valley areas, a feature that is probably the result of differences in physical properties of water-bearing materials. The changes in stage of average water level in the two lowland areas are in part the result of heavy pumping. The relation between ground-water levels, precipitation, and pumping will be more evident as more records become available.

COOPERATIVE GROUND-WATER INVESTIGATION IN CONNECTICUT[1]

BY JOHN G. FERRIS[2]

[*Read September 25, 1941.*]

For many years the ground-water resources of Connecticut have been utilized for domestic, industrial, and public supplies. The need for information as to the ground-water conditions in the State resulted in a number of early investigations and the publication of more than ten reports during the period 1903 to 1929. These studies were carried on as coöperative investigations by the Federal and State Geological Surveys. Many of the larger industrial supplies were developed in the coastal areas where there was a possibility that salt-water intrusion would take place as a result of the pumping. In 1919, a detailed investigation of the ground-water resources of the New Haven area indicated that local over-pumping had resulted in salt-water intrusion.[3]

An investigation of the ground-water conditions in Connecticut was started in October 1934, as a project of the Federal Relief Administration (replaced by the Works Progress Administration in 1935), under the sponsorship of the State Planning Board and the State Water Commission, and under the technical direction of the U. S. Geological Survey. The results of an inventory of wells and springs and a tabulation of periodic measurements of water levels in selected wells, collected through December 1937, were published in November 1938, as bulletins GW-1 to GW-6 of the Works Progress Administration for Connecticut. This work indicated that conditions in the coastal areas were more critical than in 1919. Moreover, it seemed likely that further over-development would take place with the rapid increase in the use of ground water for air-conditioning. These conditions indicated the desirability of starting a systematic program of collecting basic data that would show the trend of over-development. In 1939, it

[1]Published with the approval of the Director, U. S. Geological Survey.

[2]Assistant Engineer, U. S. Geological Survey.

[3]Brown, J. S., A study of coastal ground water, with special reference to Connecticut: U. S. Geol. Survey Water-Supply Paper 537, p. 41, 1925.

Brown, J. S., Ground water in the New Haven area, Connecticut: U. S. Geol. Survey Water-Supply Paper 540, pp. 102-103, 1928.

became necessary to curtail the work being carried on by the Works Progress Administration. Accordingly, coöperation between the U. S. Geological Survey and the Connecticut State Water Commission was arranged for the purpose of following the effects of pumping in the more highly developed areas. This coöperative investigation, which is still in progress, thus far has been confined chiefly to the New Haven area.

The coastal areas of Connecticut are underlain by bedrock which, in most places, is covered with a thin mantle of glacial till and stratified drift. These glacial deposits are the chief source of ground water in the coastal areas. The ground-water conditions in New Haven, the largest city on the south shore of Connecticut, may be considered as generally representative of the ground-water conditions along the coast, although the total draft in New Haven is probably greater than in other coastal towns.

The city of New Haven, covering an area of 22.3 sq. miles, occupies a horseshoe-shaped lowland, less than 70 ft. above sea level, which opens to the south on Long Island Sound. The West, Mill, and Quinnipiac Rivers flow through the town and discharge into New Haven Bay. Near the mouths of these streams, on the floor of the bay, are deposits of impervious mud as much as 35 ft. thick. These deposits extend up the valleys and along the shore as far as the high tide line. Nearly all of New Haven is underlain by Triassic sandstone, which is covered by stratified glacial drift in two-thirds of the area and by till in the other portion. Although the maximum thickness of the stratified drift is unknown, a well drilled in the south-central part of the city, about 1200 ft. inland, was reported to have penetrated 264 ft. of the drift before reaching bedrock. Ground water in the till and stratified drift of this area occurs under water-table or unconfined conditions except in the vicinity of New Haven Bay and in the river valleys, where deposits of mud act as a confining layer to produce artesian conditions.

Manufacturing is the chief industry in New Haven, and most of the industrial plants are located within an area less than a mile in diameter at the mouth of the Mill River. More than 100 industrial plants in the city use ground water for such purposes as refrigeration, ice and beer making, acid pickle, paper pulp manufacture, and air conditioning. The average daily withdrawal of ground water for these uses is somewhat less than four million gallons. Prior to 1924, about

90 per cent of the ground water pumped annually was derived from gangs of shallow, driven wells, three inches or less in diameter. According to reports, the yield of 3-in. wells in New Haven ranges from about 10 g.p.m. to more than 100 g.p.m. In 1924, large-diameter, gravel-pack wells were installed at some plants to replace the older wells, and by 1940, more than half of the total withdrawal was derived from gravel-pack wells. The yield of gravel-pack wells in this area ranges from about 70 to 550 g.p.m. with yields per foot of draw-down ranging from less than 4 g.p.m. to about 24 g.p.m.

In Figure 1, New Haven has been divided into four areas based

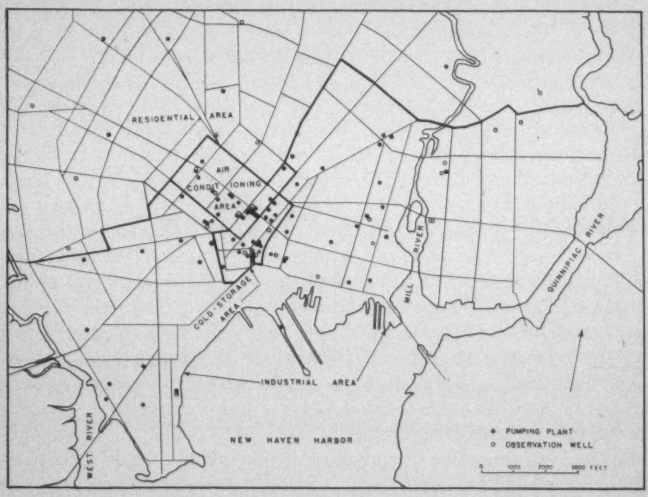

FIG.1.- MAP OF PART OF NEW HAVEN, CONN.
SHOWING LOCATION OF PUMPING PLANTS AND OBSERVATION WELLS

on the chief use of ground water in each area. These areas, although somewhat arbitrary, constitute a convenient division for the purpose of pumpage inventory, ground-water level observations, and chloride sampling. The "residential area" comprises the north upland part of the town, where there are relatively few wells, most of which have

only small capacity. However, at widely separated locations in this area, there are a few industrial plants that pump considerable water. The "air-conditioning area" includes the business section, in which theaters, stores, restaurants, etc. use ground water for air conditioning. The "cold-storage area" extends along State Street from Columbus Avenue to Grand Avenue. In this area, ground water is used chiefly for refrigeration in storing meat and dairy products. The "industrial area" is in the vicinity of the West and Mill rivers, where ground water is used chiefly for manufacturing purposes.

At the present time, water-level measurements are being made each week in 24 observation wells, one of which is equipped with an automatic water-stage recorder. These records are published annually in Water-Supply Papers of the Geological Survey. Unpublished records are on file in the following offices: U. S. Geological Survey in Washington, D. C., Hartford, Conn., and Jamaica, N. Y.; Connecticut State Water Commission, Hartford, Conn.; New Haven Department of Health, New Haven, Conn.; and New Haven Department of Public Works, New Haven, Conn. The measurements are made from clearly marked, substantial points at or near the top of the well, such as top of casing, top of coupling, or top of recorder shelf. Instrumental levels have been run to each well to determine the altitude of the measuring point above mean sea level. Sixteen of the observation wells are driven wells ranging from 1¼ to 3 in. in diameter, 6 are drilled wells ranging from 5 to 8 in. in diameter, and 2 are dug wells ranging from 30 to 120 in. in diameter. Twenty-two of the wells are screened in stratified glacial drift, and the other two end in bedrock. These wells are located as follows: 5 in the residential area, 4 in the air-conditioning area, 3 in the cold-storage area, and 12 in the industrial area. At the end of August 1941, water levels in the residential area ranged from about 3 to 25 ft. above mean sea level; in the air-conditioning area from about 3 to 14 ft. above mean sea level; in the cold-storage area from about 1 to 2 ft. below mean sea level; in the industrial area (excluding the two bedrock wells) from about 3 ft. above mean sea level to 13 ft. below mean sea level. The water level in most of the industrial area is below mean sea level.

Figure 2 shows the detailed fluctuations of water level in a well located in the western part of the industrial area. The graph has been traced from the recorder chart for the week May 7 to 14, 1941. The

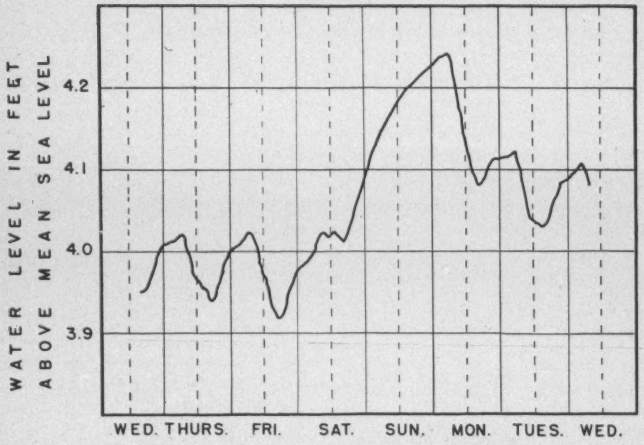

FIG. 2.- GRAPH SHOWING FLUCTUATION OF WATER LEVEL IN A WELL IN NEW HAVEN, CONN.

well is 16 ft. deep, 10 ft. in diameter, and ends in stratified glacial drift. The major fluctuations shown in Figure 2 are the result of industrial pumping at a plant about 300 ft. from the observation well. This pumping produces a draw-down that is clearly recorded at this distance. It will be noted that during the working part of each day the water level declines and that recovery takes place during non-working periods, the longest of which is the week-end.

Figure 3 shows the month by month relation between average water level, pumpage, and precipitation. The average water-level method is convenient in studying water-level fluctuations in a group of wells. The water level in each of 21 observation wells on July 28, 1939, was assigned an elevation of 20 ft. above an assumed zero datum at each well. The weekly measurements nearest the end of each month were expressed as elevations above this assumed datum. The average water level for each of the four areas is the arithmetic average of the water levels in all wells measured in that area in terms of the assumed datum. From time to time, observation wells have been added or deleted as the

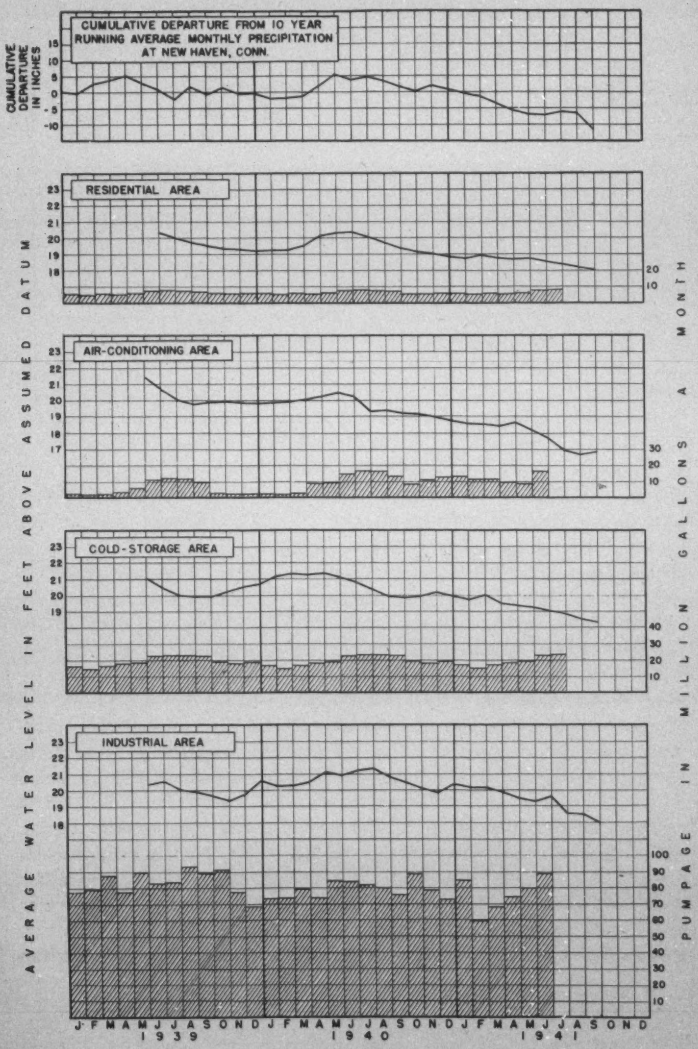
CUMULATIVE DEPARTURE FROM 10 YEAR RUNNING AVERAGE MONTHLY PRECIPITATION AT NEW HAVEN, CONN.
CUMULATIVE DEPARTURE IN INCHES
RESIDENTIAL AREA
AIR-CONDITIONING AREA
COLD-STORAGE AREA
INDUSTRIAL AREA
AVERAGE WATER LEVEL IN FEET ABOVE ASSUMED DATUM
PUMPAGE IN MILLION GALLONS A MONTH
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1939
1940
1941

FIG.3-GRAPH SHOWING RELATION BETWEEN GROUND-WATER LEVEL, PUMPAGE, AND PRECIPITATION AT NEW HAVEN, CONN.

program of measurements was shifted to secure a better distribution of wells. In general, this had very little effect on the water-level averages. When a new well was added, it was assigned a value equal to the average water level in all other wells in that area on that date.

The cumulative departure from average monthly precipitation at New Haven is shown in Figure 3. The monthly average from which each departure was determined is based on the precipitation during the preceding 10 years. During the 16-month period ending September 1941, the accumulated deficiency of precipitation was about 17 in. The precipitation was above average for only three months of this period. The unfavorable distribution and deficiency in precipitation are responsible, in part, for the low water levels at the present time. The curves of average water level in each of the areas show seasonal trends, generally with a high point in the spring and a low point in the fall. The up-trend occurs during the non-growing season, when ground-water recharge normally takes place and when water levels are recovering from the preceding period of heavy pumping. The down-trend occurs during the growing season, a period unfavorable for recharge. This is also the period of heavy pumping. In comparing the data shown in Figure 3, it should be kept in mind that the curves of average water level are based on measurements made near the end of each month. In some instances, therefore, detailed comparisons may not be evident because of unequal distribution of precipitation or pumpage during the month preceding the date on which average water levels were determined.

The fluctuations of ground-water level in the residential area are determined chiefly by precipitation, although changes in water level may result from the scattered pumpage in this area or the pumpage in nearby areas. During the cooling season, starting about June each year, water levels in the air-conditioning area are affected in large part by the pumping in the area as shown by the down-trend of the curve of the average water level in the summer of each year. The slight up-trend in August 1940, is probably the result of a decrease in pumping because of relatively cool weather during the last half of the month. The fluctuations of water level in the cold-storage area are in part the result of daily changes in rate of pumping in the area. The rate of pumping from day to day is determined chiefly by changes in air temperature. Pumping is the principal factor affecting water

levels in the industrial area. The up-trend of the average water-level curve for this area in December of each year is due to a large decrease in pumping during the holiday period. Most manufacturers in New Haven reduce their pumping greatly at this time, during factory maintenance, clean-up, and materials inventory. To a less extent, a similar shut-down occurs during the July 4 holiday period.

The monthly withdrawal of ground water in each of the four areas is shown in Figure 3. These data are based on meter records, pump displacement records, or estimates made by the plant engineers. The following table shows the pumpage in each of the four areas for 1940.

PUMPAGE OF GROUND WATER IN NEW HAVEN, CONN., IN 1940

Area	Number of Plants	Pumpage M.G.D.	Pumpage Per Cent Metered
Residential	7	0.20	0
Air-conditioning	25	0.32	47
Cold-storage	16	0.62	0
Industrial	36	2.57	62
Four areas combined	84	3.71	47

It will be noted that most of the ground water withdrawn in New Haven is pumped in the industrial area. About two-thirds of the water withdrawn in this area is pumped by five plants located along a stretch of the Mill River less than one mile long. More than two-thirds of the total draft in the cold-storage area is withdrawn by a single plant. Pumping for air conditioning, which is also confined to a small area, is rapidly increasing, although since the early part of 1940 some water has been returned to the ground.

In 1919, the chloride content of water from wells in the Mill River area indicated that salt-water encroachment had already taken place in this area.[4] Brown pointed out that further salt-water encroachment probably would occur if heavy pumping were continued in areas close to salt water.

The results of an intensive chloride-sampling program by the Works Progress Administration in 1938 and 1939 provide a basis for comparing the differences in chloride content of ground water at eight plants in New Haven in 1919 and in 1939. This comparison shows

[4]Brown, J. S., A study of coastal ground water with special reference to Connecticut: U. S. Geol. Survey Water-Supply Paper 537, p. 40, 1925.

that at six plants the chloride content increased and at two plants it decreased. At the two plants where the chloride content decreased, the pumpage also had decreased. Of the six plants at which the chloride content increased, the pumpage had increased at one plant, decreased at two, and was unchanged at the other three. In 1938-39, 28 pumping plants, located within 2500 ft. of tide water, were sampled. Of these, 13 showed chloride contents of 100 p.p.m. or more, and five showed chloride contents of 200 p.p.m. or more. Ten of the 15 plants sampled in the cold-storage area showed chloride contents of 100 p.p.m. or more, and two showed chlorides in excess of 200 p.p.m.

A monthly program of collecting samples of ground water for chloride determination was started in the New Haven area on July 30, 1941, with the collection of samples from 24 pumping plants. The determinations of the chloride content of these samples were made by the Connecticut State Agricultural Experiment Station, at New Haven, under the direction of Dr. E. M. Bailey, chemist. In addition to these 24 samples, three samples were collected and analyzed by a plant in the industrial area, as a part of a systematic program of following the changes in chloride content of its private water supply. The range in chloride content in three of the areas in New Haven on July 30, 1941, may be summarized as follows:

Area	No. of Samples Collected	Chloride Content (P.P.M.) Lowest	Highest
Air-conditioning	2	24	34
Cold-storage	14	14	1612
Industrial	11	32	3025

Of the 14 pumping plants sampled in the cold-storage area, seven plants showed chlorides in excess of 100 p.p.m., four of which had chloride contents in excess of 300 p.p.m. These four plants are all located in a narrow area less than 500 ft. long. The present chloride sampling program will provide a basis for studying the changes in salinity as more records become available. A comparison of the results so far obtained indicates in a general way that the chloride content of ground water in parts of New Haven has increased since 1919.

"RED WATER"—CAUSES AND ELIMINATION

I. LAIRD NEWELL*

[*Read December 18, 1941.*]

The annual loss of iron and steel due to corrosion has been estimated to be approximately 2 per cent of the total tonnage in use. This represents a tremendous waste of materials that can be controlled in most instances and losses brought to an insignificant amount. Water works operators in particular have several methods at their disposal for the control of corrosion of pipe lines and equipment.

While the first noticeable effect of corrosion of a distribution system may be discoloration of the water, other more insidious effects are also taking place which may not be so easily noted. The pitting of iron pipe due to corrosion may weaken the pipe until failure occurs. The formation of rust tubercles in the pipe may reduce the size of the pipe and thereby its carrying capacity. Records have shown that the carrying capacity of a 6-in. pipe may be reduced as much as 85 per cent in 30 years by a corrosive water. Household plumbing systems are frequently affected at a much greater rate.

Two obvious methods are indicated to control this loss by corrosion. First is the use of materials that are subject to little or no corrosion. These materials include the copper and nickel alloys which are strategic war materials and not obtainable for ordinary use. The choice of these materials is not included in this paper. Second is the treatment of the water to change its characteristics and reduce its tendency to corrode iron and steel.

The corrosion of iron is due to its solubility in water. This solubility increases as the acidity of the water increases and will be noted by low pH values of the water. The products formed when iron dissolves are soluble iron (ferrous) hydroxide and hydrogen. If the water is free from dissolved oxygen and undisturbed, no further solvent action would take place due to the protective action of the hydrogen deposited on the metal surface. All surface waters contain dissolved oxygen, and ground waters stored in standpipes, pres-

*The Henry Souther Engineering Co., Hartford, Conn.

sure tanks, or other reservoirs take up dissolved oxygen so that the protective hydrogen film is destroyed and the soluble iron hydroxide is oxidized to the insoluble (ferric) hydroxide which deposits on the surface of the pipe. This coating affords some protection, but it is unstable and a slight change in the character of the water will remove it, thus starting the action over again.

In addition to dissolved oxygen, practically all natural waters contain some free carbon dioxide which is in the form of carbonic acid. Since increased amounts of free carbon dioxide lower the pH of the water (increase the acidity), it follows that the rate of corrosion of iron in such a water would be accelerated.

The extent or rate of corrosion of a distributing system may of course be noted by removal of pipe from parts of the system for examination. Increased friction loss may also develop, but, in general, if the increase in the iron content of the water in passing through the system exceeds 0.2 p.p.m., it is an indication of serious corrosion. (Red water trouble represents the most noticeable feature of corrosion.)

From the foregoing considerations, several methods of reducing or preventing corrosion are suggested.

The removal of dissolved oxygen from the water would prevent corrosion if the pH of the water is above 7.0, but this is not feasible with public water supplies due to the high cost. It is done, however, in the case of private systems where expensive equipment, such as steam boilers, is involved. The oxygen is removed by de-aerators using heat or reduced pressure, or both.

Treatment of water supplies by aeration will effectively reduce the free carbon dioxide content of most waters to between 3.0 and 5.0 p.p.m. This amount of carbon dioxide would not be corrosive to iron or steel if the alkalinity exceeded 80 p.p.m. Therefore, such waters could be corrected by aeration alone. However, most New England surface waters are soft and relatively low in alkalinity, so that aeration alone is not a satisfactory treatment. In fact, with waters containing only a few parts of free carbon dioxide, aeration may increase the corrosive tendencies due to increase in the dissolved oxygen content.

Chemical methods may also be employed to remove carbon dioxide from the water. Lime, soda ash, or limestone are commonly

used for this purpose. One grain per gallon of lime will remove about 9½ p.p.m. of CO_2 and one grain per gallon of soda ash will remove about 7 p.p.m. of carbon dioxide. If the hardness of the water is low, it may be advantageous not to remove carbon dioxide by aeration but to remove it with lime and increase the alkalinity and hardness to the point where a protective film will form. This treatment may, however, render the water less satisfactory for certain industrial uses.

Protective film formation depends on the use of proper amounts of soda ash or lime, or both, so that the solubility of calcium carbonate in the water is slightly exceeded. Tillmans (1) first developed the relationship between pH, alkalinity, and carbon dioxide which he called "aggressive" carbon dioxide (2), and von Heyer (3) proposed the so-called "marble test" which is now used to indicate the equilibrium point in film formation.

If a water contains no free carbon dioxide, it will require a calcium carbonate alkalinity of at least 35 p.p.m. to obtain film formation (See Fig. 1). If the alkalinity is not made up entirely of calcium carbonate, then the water will need to be adjusted with soda ash and lime to obtain the film.

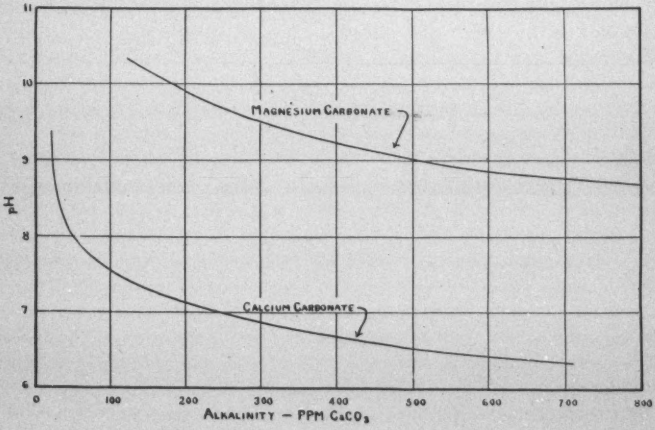

FIG. 1.—SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES AT 72° F.

Langelier (4) has developed a system based on chemical equilibrium which will indicate whether a water is corrosive, at equilibrium, or overtreated. The mathematical relationships are rather complicated, based on complete chemical analysis of the water, but laboratory tests using the von Heyer marble test, or modifications of it, give the stability index.

Briefly, it is only necessary to determine the pH of the raw or treated water and the pH of the treated water which has been subjected to the marble test and to note the difference between the two results. If the pH of the raw or treated water is lower than the pH of the water at equilibrium by the marble test, the water is corrosive. If, however, the pH is higher than the equilibrium point, that water will deposit a film which will continue to grow in thickness.

As an example, let us take a water with a pH of 7.0 and a calcium carbonate alkalinity of 50 p.p.m. If this water, when subjected to the marble test, showed a pH of 8.0, the equilibrium point would be 8.0 and the Langelier Index 7.0 minus 8.0, or —1.0. Such a water would be corrosive. If this same water had an original pH of 8.0 and the pH, after the marble test, was 8.0, the Langelier Index would be 8.0 minus 8.0, or 0. Such a water would be neither corrosive nor film forming. On the other hand, if the original water had been overtreated and showed an original pH of 9.0 and, after the marble test, a value of 8.0, the index would then be 9.0 minus 8.0, or +1.0. Such a water would be non-corrosive but would deposit a calcium carbonate scale on the inside of the pipe.

Therefore it is desirable to determine the equilibrium point for finished waters in order to keep the Index as near zero as possible. It is not possible to choose lime or soda ash at random and treat the water to obtain the desired pH and expect to prevent corrosion. This is because of the fact that sufficient calcium carbonate must be present for saturation under the conditions present. For instance, a water devoid of carbon dioxide, as is often the case when large amounts of algae are present, should not be treated entirely with hydrated lime since it could not form the carbonate under these conditions. A soft water containing only small amounts of calcium salts should not be treated with soda ash, as this chemical alone would not build up the lime to the necessary concentration to prevent corrosion.

The chemical relationships at the equilibrium point are rather

complicated, and the original investigation to prevent corrosion should be made by persons qualified by training and experience for such work. The water may then be kept at the equilibrium point by intelligent operators, not necessarily trained chemists or engineers.

A number of phosphate compounds have been used for some years in boiler water conditioning to prevent scale formation, but it was not until recently that it was known that certain of these compounds would minimize the corrosion of piping. The pyrophosphates, to some degree, and the metaphosphates, to a considerable degree, tend to inhibit corrosion. The compound most widely used for this purpose is sodium hexametaphosphate, a glasslike substance, acid in reaction, and free from water. The exact mechanism of corrosion prevention by this type of treatment is not known, but it has been found that the phosphates are strongly adsorbed on metal and oxide surfaces and prevent further growth of rust films. The process has been called "threshold treatment".

Strangely enough, the concentrated solution of sodium hexametaphosphate is exceedingly corrosive, and equipment used to feed the chemical into the system should be of corrosion-resistant material such as porcelain or hard rubber. The dose applied is generally between 1 and 2 p.p.m., although large distribution systems often require somewhat greater amounts.

Although the results of numerous investigations have shown the metaphosphates to be non-toxic, a paper by J. K. Hoskins,[5] U. S. Public Health Service, states, ". . . until reliable data on the physiological effects of polymetaphosphates are obtained, their use in excess of 2.0 p.p.m. should be avoided".

One disturbing effect in the use of sodium hexametaphosphate is the increase in the bacterial counts that have been noted by several operators (6, 7). At the Bristol Filter Plant which is using this treatment, the quality of the water from the standpoint of bacteria was maintained in an excellent condition by the use of an increased amount of chlorine. The pH of the water was held within the range 8.0 to 8.8 for the first few months by the use of lime. Lime treatment has now been stopped, and the pH is within the range 6.3 to 7.0 with no increase in the bacterial counts.

Through the kindness of Mr. G. E. Lourie, Superintendent of the Bristol Water Department, and Mr. Clair Lourie, Chief Operator

of the filter plant, the following details of operation using sodium hexametaphosphate, are presented:

	Meter Shop	Belridge Road	Maple Avenue
Before Treatment			
pH	8.3	8.8	8.8
Alkalinity (p.p.m.)	15	18	20
Color (p.p.m.)	4	100	50
Iron (p.p.m.)	0.016	3.8	1.8
Dissolved Oxygen	Saturated	—	—
One Week after Treatment with 2 p.p.m. $(NaPO_3)_6$			
pH	8.5	8.5	8.4
Alkalinity (p.p.m.)	15	16	15
Color (p.p.m.)	3	60	30
Iron (p.p.m)	0.004	0.36	0.4
$(NaPO_3)_6$ (p.p.m.)	1.4	0.7	0.8

The whole system was then flushed and the treatment with sodium hexametaphosphate was reduced to 1.5 p.p.m. Further color reductions were noted, and the iron content decreased.

About two months after the treatment was started, the results at the same sampling points were as follows:

	Meter Shop	Belridge Road	Maple Avenue
pH	8.4	8.8	8.1
Alkalinity (p.p.m.)	14	15	11
Color (p.p.m.)	1	2	12
Iron (p.p.m.)	0	0.09	0.35
$(NaPO_3)_6$ (p.p.m.)	0.7	0.4	0.2

After nine months of operation, feeding 1.5 p.p.m hexametaphosphate, the conditions are recorded as follows:

	Meter Shop	Belridge Road	Maple Avenue
pH	6.3	6.9	6.7
Alkalinity (p.p.m.)	3	12	13
Color (p.p.m.)	4	3	3
Iron (p.p.m.)	0	Trace	0
$(NaPO_3)_6$ (p.p.m.)	1.3	0.2	0.2

These figures show that the effect of the phosphate is not immediate, and that sufficient chemical must be used to reach the ends of the system.

In connection with the treatment of water with chemicals, a nomogram has been prepared whereby the calculations necessary for proper treatment are greatly simplified (see Figure 2). It is simply necessary to draw a line through the points representing the flow of

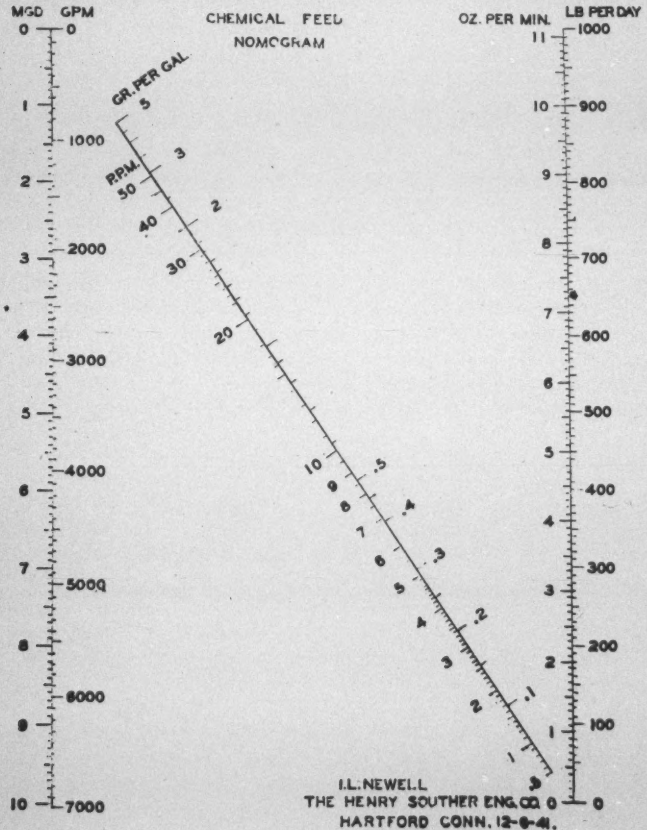

FIG. 2.—CHEMICAL FEED NOMOGRAM.

water and the dosage, and read immediately the pounds necessary. While the Rate of Flow Scale is graduated from 0 to 10 m.g.d., there is no reason why this chart cannot be used for flows outside this range by using multiples of 10.

In conclusion, it should be stated that there is no panacea for "red water". Methods which produce satisfactory results with one supply will probably not be satisfactory with another. A study of the conditions present in the system and the character of the water will, however, lead to the most economical and satisfactory method for preventing "red water".

The writer wishes to acknowledge the helpful suggestions of Mr. James A. Newlands, President of the Henry Souther Engineering Co., in the writing of this paper.

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EXPERIMENTS WITH TUBE-LOY PIPE

BY ROBERT SPURR WESTON*

[*Read November 25, 1941.*]

With the shortages of iron, copper, and zinc that preparations for national defense have caused, there has come a shortage of service pipes made of these metals. It, therefore, is of interest to learn of the possibilities of a new alloy of lead—as yet more plentiful than other metals—known as Tube-Loy. This pipe is made for services and consists of lead alloyed with small amounts of calcium, magnesium, and tin. The results of chemical analysis are as follows:

TABLE 1—COMPOSITION OF TUBE-LOY

Element	Per cent
Calcium, Ca	0.020
Magnesium, Mg	0.015
Bismuth, Bi	0.020
Tin, Sn	0.25
Lead, Pb	Balance

The manufacturers of this new pipe—the American Smelting & Refining Company—are making two types of it, known as Type "A" and Type "K", respectively.

TABLE 2—DIMENSIONS OF TUBE-LOY PIPES
(Inches)

Nominal Sizes	Type "A"		Type "K"	
	Inside Diameter	Outside Diameter	Inside Diameter	Outside Diameter
3/8	—	—	0.375	0.500
1/2	—	—	0.469	0.625
5/8	—	—	0.580	0.750
3/4	0.815	1.125	0.695	0.875
1	1.050	1.375	0.900	1.125
1 1/4	1.281	1.625	1.094	1.375
1 1/2	1.688	2.125	1.281	1.625
2	2.094	2.625	1.688	2.125

*Of Weston & Sampson, Consulting Engineers, 14 Beacon St., Boston.

The diameters of the two types of pipe may be compared with their nominal sizes, as shown in Table 2.

How the dimensions and weights of Tube-Loy compare with those of Class AA and Class AAA lead pipe, as shown by the figures for 1-in. pipes, is given in Table 3.

TABLE 3—COMPARISON OF DIMENSIONS AND WEIGHTS OF TUBE-LOY AND LEAD PIPES

	Tube-Loy		Lead	
	Type A	Type K	Class AA	Class AAA
Inside Diameter (inches)	1.050	0.900	1.00	1.00
Outside Diameter (inches)	1.375	1.125	1.48	1.60
Thickness of Wall (inches)	0.1625	0.112	0.24	0.30
Weight per foot (pounds)	3.02	1.69	4.75	6.0

Tube-Loy has remarkable strength, tests having shown that it can be used at higher working pressures than either Class AA or Class AAA lead service pipe. It can be safely employed for all steady working pressures up to 125 lb. per sq. in. in spite of the fact that the weight is less even than that of Class AA regular lead pipe. For this reason, Tube-Loy is not only moderate in cost, but it is also ductile and easily handled even in long lengths. It possesses the advantages of lead pipe including the practicability of wiped joints. Furthermore the outside diameters are such as to allow the use of standard flare-type or sweat-type fittings, should these be preferred for jointing. Type A Tube-Loy has a larger inside diameter than regular lead pipe of the same nominal size and, therefore, a larger carrying capacity. Type "K" Tube-Loy was used in the tests at Milford that are described in this paper. Also used was Chromate Tube-Loy, being pipe of the same metal with a coating of lead chromate—a slightly soluble salt of lead—formed on its inside surface.

Naturally, one associates lead pipe with lead poisoning (plumbism). Lead poisoning by water began with the use of pipes of that metal by the ancients, and in the Second Report (1871) of the Massachusetts State Board of Health there is a record of the experimental study of the effect of various waters on lead pipe, by Professor William Ripley Nichols, then head of the Department of Chemistry at the Massachusetts Institute of Technology. In the 90's, cases of lead poisoning were prevalent in many places, including a few in

Massachusetts, and in that decade there appeared the thorough report by H. W. Clark (1).

The possibility of lead poisoning was recognized by the American Smelting & Refining Company, and Dr. Albert J. Phillips, Superintendent of the Research Department, asked the assistance of the writer's firm in testing the new pipe. The result was that the Milford Water Company, with its plumbo-solvent raw water, was asked to coöperate in making the tests. The request was granted, and tests were begun in January, 1941.

The Milford water was recommended for the tests because of its history (2). The original works, built in 1881 and supplying the towns of Milford and Hopedale, took its supply from three wells along the Charles River, and most of the services in the two towns were of lead. The water was one, of four in Massachusetts, that the State Board of Health found to be causing serious lead poisoning (1) because of the solvent action of the ground water, which was clear, colorless, soft, nearly free from organic matter, and contained oxygen and carbon dioxide gases.

At the time of the studying of the problem by the State Board of Health, many cases of plumbism among Milford and Hopedale residents were in the hospitals; so, in 1903, to overcome the danger without replacing the costly services, the Company built slow filters. Thereafter, the consumers were daily supplied with filtered water from the Charles River, although the effluent of the filters was discharged into the wells and mixed with the yield of the latter.

Following the placing of the filters in service, cases of lead poisoning disappeared, and until 1914 the Company believed that it had done everything necessary to protect its consumers. In that year, however, one suspicious case of plumbism occurred. While the patient, in this case, may have been unusually sensitive to the poisonous effect of lead, and it was true that the supplied water was drawn through a long service, examination of the filter and its product indicated that between January, 1904, and June, 1914, when the tests were made, a large amount of organic matter derived from the highly colored Charles River water had been gradually stored in the filter sand. The organic matter in the sand had fermented and produced carbon dioxide. This was shown by many determinations of this gas, and of oxygen as well, in both the influent and effluent of the

Milford Water Company's filters. The results were as shown in Table 4.

TABLE 4—CARBON DIOXIDE AND DISSOLVED OXYGEN IN MILFORD WATERS, 1914
(Parts per million)

	Carbon Dioxide			Dissolved Oxygen		
	Av.	Max.	Min.	Av.	Max.	Min.
Charles River	7.15	8.5	6.2	8.32	8.73	7.89
Filter Effluent	15.1	16.8	13.5	5.77	6.49	5.02

Following the re-occurrence of carbon dioxide in the softer delivered water and the consequent solution of lead from the services, experiments were made which showed that it was necessary to treat the water to inhibit the corrosive action of the water upon lead and that treatment with lime was effective. This treatment was begun in December, 1914. Since then, the average dose of hydrated lime has been about 12 p.p.m., or 100 lb. per m.g. of delivered water.

Since this treatment was started, samples have been taken from a test service under conditions of standing overnight and ordinary use, respectively, and the amounts of lead determined with the results given in Table 5.

TABLE 5—AMOUNTS OF LEAD IN WATER FROM MILFORD TEST SERVICE
(Parts per million)

		Lead	
		Standing Overnight	Ordinary Use
	1936	0.083	0.032
	1937	0.031	0.033
	1938	0.034	0.021
	1939	0.035	0.024
	1940	0.035	0.027
January 13,	1941	0.045	0.015
March 4,	1941	0.024	0.020
April 8,	1941	0.040	0.018
May 27,	1941	0.060	0.014
June 9,	1941	0.047	0.037
August 11,	1941	0.020	0.010
September 29,	1941	0.020	0.015
(Seven tests)	1941 Average	0.037	0.018

In 1940, the average results of analyses of the water before and after treatment with lime and chlorine were as recorded in Table 6.

TABLE 6—AVERAGE RESULTS OF ANALYSES OF MILFORD WATER BEFORE AND AFTER TREATMENT, 1940

Determination	(Parts per million) Raw Water	Treated Water
Color	23	22
Hardness	13.5	28.0
Alkalinity, Total	8.3	21
Alkalinity, Carbonate	—	4.7
Iron	0.18	0.17
Oxygen Consumed	4.4	4.0
Carbon Dioxide	12.9	0.9
Dissolved Oxygen, % of Saturation	65.6	73.7
Residual Chlorine	—	0.24
pH Value	6.1	7.9

The results of partial analyses of raw and treated water made during 1941, part of them to control the treatment of the water and

TABLE 7—RESULTS OF ANALYSES OF RAW AND TREATED MILFORD WATERS DURING TUBE-LOY TESTING PERIOD
(Parts per million)

	Temp. °C.	Color	Oxygen Consumed	Alkalinity	Hardness	pH Value	Carbon Dioxide	Dissolved Oxygen % Sat.
RAW WATER (Well No. 1)								
January 8	3.0	—	—	—	—	6.1	8	85
January 9	3.0	—	—	—	—	6.3	7	77
January 15	2.5	18	—	6	—	6.0	9	85
January 22	2.0	20	—	7	—	6.2	7	88
February 6	4.0	17	—	6	—	6.0	7	85
February 21	3.5	20	—	6	—	5.9	8	81
March 3	—	15	4.2	5	14	6.1	—	—
March 10	4.0	16	—	6	—	6.2	8	88
April 10	8.5	20	—	10	—	6.1	10	74
May 12	14.0	25	—	20	—	6.6	8	73
May 20	—	30	6.2	7	12	5.9	—	—
June 13	17.5	18	—	10	—	6.0	10	60
August 12	22.5	9	—	8.5	—	5.9	12	66

TABLE 7 (*Continued*)

	Temp. °C.	Color	Oxygen Consumed	Alkalinity	Hardness	pH Value	Carbon Dioxide	Dissolved Oxygen % Sat.
TREATED WATER (Tap)								
January 8	4.0	—	—	—	—	7.6	1	—
January 9	6.5	—	—	—	—	8.4	0	83
January 15	5.5	18	—	18	—	7.1	2	89
January 22	3.0	20	—	15	—	7.4	1	91
February 6	4.5	18	—	14	—	7.1	3	89
February 21	6.5	20	—	19	—	7.9	0	89
March 3	—	16	3.9	15	22	7.5	—	—
March 10	3.5	16	—	23	—	8.4+	0	86
April 10	9.0	20	—	22	—	8.6	0	85
May 12	13.5	25	—	23	—	7.3	2	74
May 20	—	30	5.5	21	24	8.4	0	—
June 13	16.5	16	—	24	—	8.4	0	69
August 12	22.0	10	—	23	—	7.9	0	66

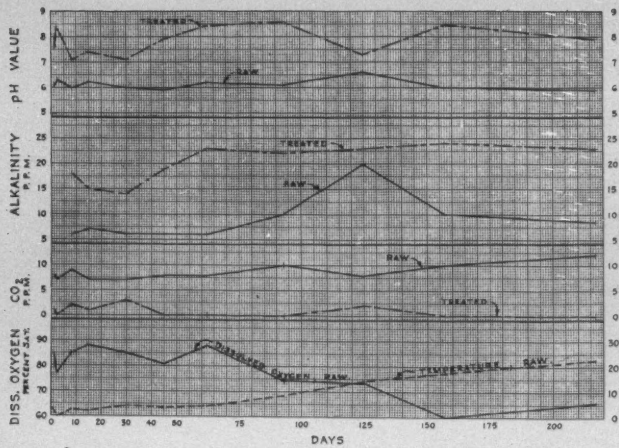
part for comparison with the waters drawn from the pipes under test, were as shown in Table 7.

It will be noted that there was a tendency for color to decrease and for the hydrogen-ion concentration and the carbon dioxide to increase during the summer. This was due to low stream flow and the throwing out of service of one or more filters for cleaning the filter sand, with consequent decrease in the ratio of filtered surface water to ground water, the latter from the old wells into which the filters drained. This circumstance, which could not be controlled, increased the corrosive action of the water. These results are plotted in Figure 1.

The variations in pH values are of importance, and are given in Table 8.

The pipes tested are shown in Table 9.

The Tube-Loy pipe was in 50-ft. lengths, and the ordinary lead pipe in lengths of equivalent interior surface. The coils of pipe were set in an isolated room, and connections were made through 12-in. lengths of non-conducting rubber-lined pressure hose. Needle valves and meters on each connection permitted accurate control of flow. Before the beginning of the tests, the pipes were filled with water and allowed to stand for 11 days. They were then flushed out, and



CHARACTERISTICS OF MILFORD WATER ; BOTH RAW AND TREATED

FIG. 1.

TABLE 8—pH VALUES OF RAW AND TREATED MILFORD WATERS, 1941

Month	Raw Water			Treated Water		
	Av.	Max.	Min.	Av.	Max.	Min.
January	6.03	6.2	5.8	7.69	8.0	7.2
February	6.00	6.0	6.0	7.76	8.0	7.4
March	6.00	6.0	6.0	7.99	8.2	7.8
April	6.00	6.0	6.0	8.11	8.4	8.0
May	5.98	7.4	5.6	8.13	8.4	7.8
June	6.08	6.4	5.8	8.11	8.4	8.0
July	6.19	6.8	5.8	8.03	8.2	8.0
August (12 days)	6.04	6.4	6.0	8.02	8.2	8.0
Whole Period	6.04	7.4	5.6	7.98	8.4	7.2

on January 7 the tests were begun. On each day, approximately 200 gal. of raw or treated water were passed through the pipes in 16 hours. The flow was then stopped and the water allowed to "stand overnight" in each pipe for the remainder of the 24 hours. The periods of sampling in numbers of days were as follows: 1 day, 2

TABLE 9—DIMENSIONS AND WEIGHTS OF PIPES TESTED

Metal	Inside Diameter (In.)	Outside Diameter (In.)	Wall Thickness (In.)	Weight per foot (Lb.)
Tube-Loy	0.900	1.125	0.225	1.69
Ditto, Chromate-coated	0.900	1.125	0.225	1.69
Ordinary Lead	0.750	1.340	0.295	4.45

days, 4, 8, 15, 31, 45, 62, 93, 125, 157, and 217. The tests ended with the sampling on August 12th.

The results of determinations of lead are given in Table 10 and illustrated in Figure 2.

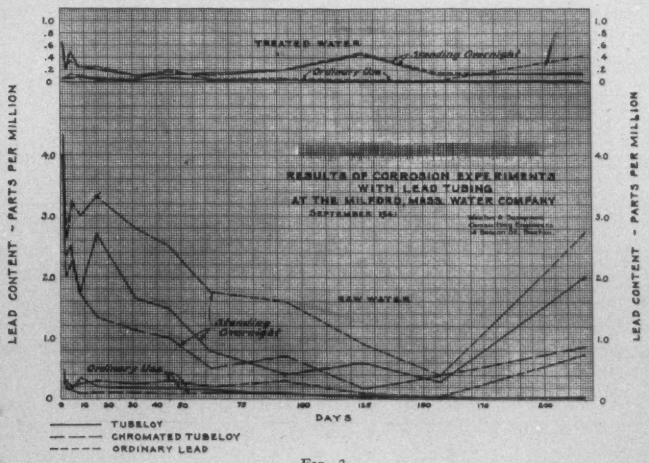


FIG. 2.

Since these tests were made, the solvent action of Milford water and of water from a large city in Pennsylvania have been compared. The latter was found to show only thirty per cent of the action upon Tube-Loy pipe exhibited by the former.

TABLE 10—LEAD DETERMINATIONS
(Parts per million)

1941	Raw Water						Treated Water			
	Tube-Loy		Chromated Tube-Loy		Ordinary Lead		Tube-Loy		Ordinary Lead	
Jan. 7	11.00		10.00		9.00		1.70		3.80	
After standing 11 days	Standing Overnight	Ordinary Use	Standing Overnight	Ordinary Use	Standing Overnight	Ordinary Use	Standing Overnight	Ordinary Use	Standing Overnight	Ordinary Use
Jan. 8	4.000	0.480	4.333	0.260	4.000	0.280	0.600	0.060	0.666	0.040
Jan. 9	2.333	0.173	2.000	0.217	2.667	0.300	0.217	0.070	0.200	0.060
Jan. 11	2.500	0.150	2.250	0.167	3.250	0.223	0.500	0.066	0.350	0.133
Jan. 15	1.750	0.350	1.750	0.088	3.000	0.250	0.250	0.090	0.250	0.100
Jan. 22	2.667	0.200	1.333	0.100	3.333	0.300	0.200	0.030	0.240	0.060
Feb. 6	1.625	0.163	1.125	0.100	3.000	0.250	0.113	0.020	0.125	0.050
Feb. 21	1.500	0.163	1.000	0.080	2.500	0.300	0.120	0.070	0.163	0.200
Mar. 10	1.000	0.150	0.500	0.100	1.750	0.200	0.150	0.030	0.100	0.050
Apr. 10	0.400	0.080	0.700	0.090	1.600	0.300	0.200	0.040	0.200	0.060
May 12	0.500	0.050	0.170	0.030	0.900	0.100	0.450	0.020	0.475	0.035
June 13	0.300	0.030	0.400	0.055	0.400	0.050	0.115	0.020	0.150	0.025
Aug. 12	2.000	0.048	0.875	0.040	2.750	0.750	0.150	0.020	0.138	0.425

Conclusions

From the results of experiments with Tube-Loy at Milford, the following conclusions may be drawn:

A. *With Raw Water*

1. *Under conditions of standing overnight*

a. The Tube-Loy pipe is more resistant to the plumbo-solvent raw water than is ordinary lead.

b. The chromate coating increases the resistance of the Tube-Loy pipe.

c. Ordinary lead is readily attacked.

d. Under these conditions, lead was dissolved in concentrations too high for safety from all pipes tested.

2. *Under conditions of ordinary use*

a. Both the Tube-Loy and the chromated Tube-Loy pipe resist the action of the raw water more than ordinary lead.

b. Ordinary lead is attacked with resulting concentrations of lead, which were too high for safety for most of the test period.

B. *With Treated Water*

1. *Under conditions of standing overnight*

a. Both Tube-Loy and ordinary lead pipe yielded excessive amounts of lead at the start and also on May 12 under these conditions, but the latter may have been due to inadequate treatment on that day.

b. As a rule, treatment was slightly more effective with the Tube-Loy than with the ordinary lead pipe.

2. *Under conditions of ordinary use*

a. Even from the beginning of the test, water from the Tube-Loy pipe contained less than 0.1 p.p.m. of lead, and during the last five months, less than 0.05 p.p.m.

b. Tube-Loy was not dangerously affected by the corrosive water of August 12.

c. Ordinary lead was seriously affected on August 12, when solvent action was at the maximum.

In brief, the tests showed that Tube-Loy pipe could be used with raw Milford water under conditions of "ordinary use". It could not be used under conditions of "standing overnight". With treated water, the Tube-Loy was more resistant than ordinary lead pipe.

All the samples in connection with the tests were collected by G. G. Bogren, and were analyzed by C. W. Hunter, both of the firm of Weston & Sampson. The daily control of the work was by the engineers of the pumping station with Nathaniel A. Spindel in charge. Mr. Madison H. Goff, Superintendent of the Milford Water Company, did everything in his power to facilitate the work. It is these men who have made possible the writing of this paper.

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RELATIVE EFFICIENCY OF ACTIVATED CARBON AND AERATION IN THE REMOVAL OF TASTES AND ODORS

BY GEORGE G. BOGREN*

[*Read September 26, 1941.*]

Of late, the development of super-chlorination in the field of odor and taste removal has captured the attention of water works chemists and engineers. It is the purpose of this discussion to compare briefly the merits of two other methods of odor and taste removal which have been the longest in use. While super-chlorination will be successful where activated carbon and aeration are not, the last two methods still will find a wide field of use.

It is unfortunate that time has not permitted a statistical study of the analytical records of plants where these two methods have been used—with the batting averages duly figured—or a series of controlled experiments with the two methods used in parallel. However, plant experience has provided the data from which general conclusions can be drawn.

Tastes and odors. Odors in water are mostly due to volatile substances. In most cases, the terms tastes and odors are synonymous. In New England, algae are the most common source. These are microscopic organisms, many of which exude volatile oils, chiefly upon their death and decomposition. These provide the spice in the field of odors,—aromatic, etc. Extracts from higher types of vegetation provide less pronounced odors, called vegetable, grassy, etc. Sewage and industrial wastes contribute a wide range of odors ranging in character from plain disagreeable to medicinal, such as phenol tastes from gas plants.

Aeration. Aeration consists of exposing the water to the atmosphere so that the volatile constituents causing the odors may escape into the atmosphere. This is done:

1. By spraying the water into the air from nozzles;
2. By spilling it over cascades, as in the spillways of dams, or over a series of trays;

*Of Weston and Sampson, 14 Beacon Street, Boston, Mass.

3. By blowing compressed air through it;
4. By mechanical agitation of the surface of the water; and
5. By trickling the water through beds of coarse material, well ventilated to the atmosphere.

The process is entirely physical; it was thought by some that oxidation was involved, but this does not seem to be the case.

Activated Carbon. This material consists of carbon made by burning various cellulosic materials, the commonest of which are lignite and wood pulp residues. The power of activated carbon to remove tastes and odors depends upon its ability to absorb the taste- and odor-producing matters. Adsorption is partly a physical and partly a chemical process. There is a limit to the amount of volatile constituents that carbon can absorb, and the quality of a carbon is measured by its adsorptive capacity which is usually expressed in terms of phenol (carbolic acid) removal.

When first introduced, activated carbon was used in granular form and placed in beds, similar to sand filters, through which the water was passed. The problem of re-activation of such beds led to the production of carbon of very fine size—particles passing a 200-mesh sieve. Because of the infinitely greater surface area exposed to the water by powdered as compared with granular carbon of equal weight, the powdered form is much more effective. Such small doses are usually used that recovery and re-activation are not feasible. In general, doses of from 2 to 10 p.p.m. of carbon are used. The size and low specific gravity of the particles require their removal from the water by filtration.

Comparative Efficiencies. To compare scientifically the two methods for the removal of tastes and odors would require some method of expression of the amounts of aeration and activated carbon required to remove an odor from a given water. For carbon, this is easy, but for aeration, it is not always possible. With aeration, the volume of air applied per volume of water treated would be a suitable measure where compressed air is blown into the water, as in the activated-sludge method of sewage treatment. For aeration by spraying, cascading, mechanical agitation, and trickling, a suitable measure would be difficult to provide. The degree of aeration in these instances cannot be measured by the amount of oxygen dissolved from the at-

mosphere, because in most cases where aeration is required, the water is already nearly or wholly saturated with oxygen.

Scientific comparison of the two methods is further rendered impracticable by the fact that complete odor removal is not always possible by both methods.

The best basis of comparison is a compilation of the various types of tastes and odors and the degree to which each method is effective in removing them. For those types of tastes and odors for which both methods are effective, the comparative costs serve as the best measure of efficiency.

Effective Field of Aeration. Thorough aeration is most successful in dealing with odors from microscopic organisms, as the odorous constituents are often highly volatile. Here, however, it should be noted that the removal is seldom complete, but usually sufficient to reduce the tastes and odors to unobjectionable limits.

Tastes and odors resulting from vegetable extracts such as the tannins in highly colored New England waters, are not so thoroughly removed by aeration. Phenolic tastes imparted by gas works and oil refineries are affected little if at all by aeration. Aromatic odors due to oil refineries sometimes are successfully treated by aeration. Tastes and odors resulting from pollution by domestic sewage and other industrial wastes (mostly disagreeable, etc.) are usually not removed in a satisfactory degree by aeration.

Effective Field of Activated Carbon. This material is remarkably effective over a wide range of tastes and odors. It will usually exceed aeration in the degree of removal of tastes and odors resulting from microscopic organisms; remove tastes and odors resulting from vegetable extracts and from bottom decomposition in reservoirs; and remove tastes and odors, of phenolic and similar origin. Activated carbon successfully treats water polluted by domestic sewage and enjoys a mixed success in waters polluted by industrial wastes. Fortunately, polluted waters, as sources of supply, are comparatively rare in New England.

Choice of Method for Taste and Odor Removal. In designing new works, the choice of method will be governed by the comparative cost of construction and operation where both methods are practical.

In adapting methods for taste and odor elimination to existing

works, the choice will often be based on expediency rather than cost.

Aeration will be more feasible:

1. In dealing with occasional seasonal complaints due to microscopic organisms, or reservoir stagnation, in waters unpolluted by sewage or industrial wastes, where sufficient head is available without additional pumping.
2. In dealing with the odors and tastes just mentioned, even though additional pumping be required, in supplies not filtered, or in supplies treated by slow sand filters, where the application of carbon would shorten filter runs to a considerable degree.
3. In dealing with the odors and tastes just mentioned, in polluted supplies where pre-chlorination is practiced. Here aeration may reduce the chlorine demand, while activated carbon would use up chlorine.

Activated carbon will be more feasible:

1. In supplies treated by rapid sand filtration plants, where head is not available for aeration, and where additional pumping for aeration would exceed the cost of carbon treatment.
2. In supplies treated by rapid sand filtration where aeration would not be effective for the types of odors encountered.
3. In supplies treated by rapid sand filtration where, in addition to removal of tastes and odors in the raw water, activated carbon will prevent growths of algae in open coagulation basins and prevent odors due to decomposition of sludge in coagulating basins.
4. In supplies treated by rapid sand filtration where activated carbon may be applied with the coagulants without the use of additional equipment. This is particularly true where odors are of infrequent occurrence.

Discussion

Stuart E. Coburn.[1] As I see it, aeration is of value for the removal of carbon dioxide, manganese, or iron, and for flash mixing of chemicals. If odors or tastes are removed by aeration incidental to its use for these purposes well and good, but to install aeration

[1]Of Metcalf and Eddy, Boston, Mass.

equipment to remove tastes and odors seems to be an expensive proposition for the results that can be obtained.

HAROLD CHANDLER.[2] I agree with Mr. Coburn. What I would like to find out is how to remove the woody taste associated with break-point chlorination.

E. A. SIGWORTH.[3] We have carried on some tests in which we have developed the so-called woody taste, and it is almost impossible to remove it economically. Further chlorination will not succeed. Even though the residual is brought back to zero by dechlorination, the taste is still there, and tremendous doses of carbon must be used in order to correct the condition. Frequently, an answer is found by treatment with carbon first in order to adsorb the impurities, followed by proper chlorination treatment.

So far as aeration itself is concerned, there are undoubtedly compounds in water that are readily removed by this treatment. Hydrogen sulfide is one. We have had instances in Texas where the hydrogen sulfide content runs up very high, several hundred parts per million, and aeration reduces that down perhaps 4 or 5 p.p.m., which is still objectionable, however. The residual can then be removed by chlorination or by activated carbon filters. In general, however, we don't find aeration to be too successful in eliminating tastes and odors. Under average conditions, aeration is only about 15 per cent effective, *i.e.*, not enough to be noticeable in the system proper. Aeration very infrequently will produce a palatable water if the water was unpalatable before aeration.

On the other hand, aeration is sometimes surprisingly effective. At Gloversville, N. Y., the plant was designed to correct tastes and odors by means of activated carbon. Feeding equipment was provided to handle 600 lb. of activated carbon per hour on a supply of perhaps 3 or 4 m.g.d. That was a tremendous dose of carbon, indicating apparently that the studies had showed a tremendous amount of taste and odor to be removed. Aerators of the diffusion type were installed and they eliminated the necessity for using activated carbon for, roughly, over a year. Whether or not they have actually en-

[2]Albany, N. Y.
[3]Industrial Chemical Sales, New York, N. Y.

countered the taste and odor conditions that existed in the supply at the time of their investigation, I don't know, but I am inclined to think not.

Aeration, in contrast, will sometimes give no results at all. We carried on some tests with water having a threshold odor of 22, and when we got through aerating it, the value was still 22. In another case an algal odor of 19 was reduced by aeration to 14. Water with a musty sewage odor of around 25 was brought down to about 20 by aeration. Exceptionally good results from aeration were experienced, however, with a mine waste odor; here the threshold odor at the start was 100 and was brought down to 40. In another instance where the starting odor was 50, aeration brought it down to, I believe, about 18. But for odors due to algal decomposition I am inclined to feel that the best expectation is about 15 to 25 per cent with aeration.

On the other hand, with activated carbon you can, if you use enough, deliver water that will be palatable.

MR. BOGREN. I agree with both Mr. Sigworth and Mr. Coburn. At the Wakefield, Mass., slow sand filtration plant, the raw water has a very distinct algal odor most of the time, but aeration reduces it enough so that there are no consumer complaints.

As I said in my paper, I don't think aeration will eliminate any kind of odor. It will reduce certain odors, however, to limits where they become unobjectionable.

W. A. HELBIG.[4] I agree with Mr. Sigworth and Mr. Coburn. Our findings have been that in most water works plants there is some reduction in odor with almost all of the steps that are used in treating the water, including filtration. The order of reduction is about the same as that obtained with aeration. As has been pointed out, that would vary with the nature of the odor, but it must be borne in mind, I think, that aeration is an equilibrium phenomenon. Therefore, there is always a residual odor present after aeration, and in many cases this is sufficiently above the average perception threshold to be troublesome.

Powdered carbon presents a very much larger surface than

[4]Darco Corporation, New York, N. Y.

granular carbon, but that is not the complete story of their relative efficiencies in water treatment. Powdered carbon is dispersed in very small dosages and gets relatively poor contact whereas with granular carbon contact with the water is very efficient. Tests have shown that powdered carbon is not always permitted to exert its full adsorption capacity before it is eliminated from the system by settling or filtration.

FRED E. SMITH.[5] At the Cambridge plant, aeration of the filtered water is accomplished by a riffle-plate aerator. Odors are removed to a limited extent by the aerator, but at present the filters are doing most of the work in odor removal.

From the standpoint of plant design and comparison of the two methods of odor removal, namely, use of carbon or aeration, the flexibility which is available in carbon treatment is, I think, the point that should be carefully considered. We have never had to use carbon, but should that treatment become necessary it could be applied to the mixing chamber or in the coagulated water as it flows to the filters. Aeration devices once installed invariably are in fixed position. Carbon treatment has much greater flexibility than aeration.

MR. SIGWORTH. In so far as individual operators being able to determine whether a certain treatment is giving taste and odor removal or not, that is a very ticklish proposition. If you feel that you are being successful in the removal of tastes and odors you can very well fool yourself. I know of instances where people have thought very definitely that they were improving the taste and odor of a water and were convinced in their own minds that the water they were delivering to the consumer was palatable. Yet, on carrying on a threshold odor test, whereby you can actually get a real measurement of the intensity and character of the odor, the water was not palatable and hardly improved at all over the original water. A lot of these ideas so far as odor removal is concerned are mental and wishful thinking for which you cannot blame the operator.

MR. COBURN. We are all talking about taste removal but we are all measuring it by threshold odor. Is there any way of knowing the threshold taste?

[5]Cambridge, Mass.

MR. SIGWORTH. We have carried out threshold taste tests and parallel threshold odor tests. At Buffalo, N. Y., and at Beaver Falls, Pa., this is certainly so. The test is not quite as sensitive as the threshold odor test and the intensity observed is lower.

One of the theories of the action of activated carbon is that if the material to be removed is relatively insoluble in water it is most easily eliminated. If it is highly soluble it is difficult to remove. Kerosene we know is relatively insoluble, whereas the woody taste might be due to highly soluble substances and therefore more difficult to remove. At Hammond, Ind., 100 p.p.m. of carbon must be added to water having 100 threshold units. In Dallas, Texas, the value varies from 50 to 100 p.p.m. when they have a threshold odor of 100. On a threshold odor of 100 I have seen a dosage of 4 p.p.m. take care of this taste in New England, in other words, 1/25th of what is normally used out through the Middle West and in the Far South. There is the same intensity of odor but the character is different.

PUBLIC WORKS PROGRAMMING IN RELATION TO THE POST-EMERGENCY PROBLEM

BY WILLIAM STANLEY PARKER*

[*Read September 25, 1941.*]

Purpose of Programming. A good deal has been written on the subject of public works programming. The Report of the President's Conference on Unemployment, in 1921, is perhaps a natural starting point for any historical references nowadays. That report analyzed at some length the causes and effects of the business cycle and asserted the need of using public works as a stabilizing factor by carrying them out in a counter-cyclical program. On this theory, more public works would be built in a depression period and less in a boom, thus tending to offset the fluctuations in the spending of private enterprise.

Many reports have been written since then on this subject. All but one support the counter-cyclical theory and apply it to all levels of government—federal, state, and local. The Report of the Massachusetts State Planning Board in 1938, entitled "A Policy for Stabilizing Public Expenditures" supports the idea of the counter-cyclical theory for federal public works but suggests a policy of "stabilized expenditures" for municipalities, due to the fact that, unlike the Federal government, local governments raise their funds by taxes on property, under statutory limitations as to debt.

It is also clear that, in the past, municipal expenditures for public works have followed the same cycle as private enterprise, municipalities spending more for capital improvements in good times and less in bad times, thus making both the boom and the depression more marked.

This paper does not afford the space required for discussion of these two proposals and the various factors that affect the extent to which they are practicable and effective. For our purpose, it is enough to point out that whichever policy is followed, it must be accomplished by some conscious control of expenditures, which is only another way of saying a public works program. Without a consciously developed program, no definite policy can be followed. To what

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extent are public works now being developed in accordance with such programs?

In this discussion, we, of course, are not referring to war emergency programs that must employ abnormal speeds and magnitudes according to the urgent need of the moment. Our discussion relates to the normal peace-time activities of governments, preferring to assume that normal peace times will some day return.

Experiments in Programming. Ever since 1931, in accord with the provisions of the Federal Employment Stabilization Act, the regular capital expenditures of federal departments have been required to be programmed by the department heads on a six-year basis. In this way, the development of institutions, or the execution of established policies in conservation, flood control, and so forth, are indicated according to a desired trend of expenditures, year by year, during the six years of the program period.

Responsibility for the administration of this programming procedure now rests with the National Resources Planning Board. It was also instructed by the President, about three years ago, to develop a procedure for the long-range programming of public works by states and municipalities. To accomplish this, a Public Works Committee was appointed, under the Chairmanship of Col. Henry M. Waite, which carried out seven experimental studies in Winchester, Mass., Nashville, Tenn.; Kalamazoo, Mich.; Fort Worth and Dallas, Tex.; Spokane, Wash., and Sacramento, Cal. These studies were for the purpose of providing a practical basis for the procedure that would result. The municipalities, one a town, the remainder cities, were widely different in size, character, geographical location, and form of government.

Only sporadic and partial efforts at programming had previously been tried. Schenectady, N. Y.; Cincinnati, O.; Milwaukee, Wis.; Richmond, Va., and a few other cities had made their contributions to the subject, but nowhere was a consistent long range programming procedure in effect.

Out of these experimental studies, there have been developed the outlines of a basic procedure that is adaptable to any state, city, or town. There is nothing mysterious about it. It constitutes merely an orderly procedure for looking ahead, for the application of organized foresight in developing the state and municipal budgets for capital

outlays. This procedure has, in the past, been applied broadly to operating expenses, using often very complete analyses of expenditures in prior years as a basis for determining needs for the coming year, or in a state for the coming biennium. But capital outlays have not had the same care in their determination.

In no case have either operating expenses or capital outlays been forecast beyond the budget period under consideration. A probable trend into the future has not been charted. While operating expenses can be forecast fairly accurately on a basis of past experience, this cannot be done with capital outlay. In its case, the trend in any given department is likely to be the reverse of the past. Future capital outlays must be programmed on a basis of need, properly related to ability to pay.

However much attention is paid to past experience as a guide to current appropriations, a clear understanding of current trends cannot be secured unless they are forecast for some reasonable period into the future. This raises the question of how long that period should be. The Federal Employment Stabilization Act adopted six years for this purpose. In doing so, it is understood that a four-year period was eliminated to avoid paralleling the presidential term and it was found inexpedient to adopt five years because Russia had just embarked on a Five Year Plan. The six-year period is about as satisfactory as can be devised. It is long enough to show trends and it is not so long that forecasting the latter years of the program becomes largely guesswork.

Programming Procedure. In its main outlines, the procedure is simple. It involves tabulating background experience in income, operating expenses, debt service, and capital outlay. These tabulations are based on the official auditor's or comptroller's reports but involve some reorganization of the figures, particularly in the clear and consistent separation of capital outlays from operating expenditures. This is not always easy, as they are generally pretty well scrambled in appropriations and financial reports.

This separation is essential in order to provide a basis for forecasts. Operating expenses generally maintain a fairly steady trend, while capital outlays, in any given department, are likely to fluctuate widely from year to year. In order to forecast operating expenses, therefore, capital outlays must be deleted and separately tabulated.

In order to forecast income, it is, of course, necessary to forecast assessed values and to determine the tax rate to be used. The forecast of assessed values, like the other forecasts, can only be the result of the best current judgment and will, of course, involve a factor of error. An essential element in the procedure, however, is its annual revision. While in each year a six-year program is laid out, only the first year is submitted for action as a budget proposal. In the next year, a new six-year program is prepared, adding a new sixth year, and readjusting the forecasts for the other years in the light of the new conditions that may have developed. Thus any errors of forecasting are continually being corrected, and each budget year has eventually been appraised five times before it is finally submitted as a budget proposal.

For capital outlays, the tabulating of past experience is of secondary value. The essential need is to determine what projects ought to be undertaken and what the city can afford to pay for during the six-year period. Department heads submit their department programs based upon need, showing the projects that should be undertaken in each year of the program period. These are coördinated with the necessary deletions, into a city-wide program, by some duly constituted programming committee, based upon the municipality's ability to pay, as evidenced by the tabulations of income and operating costs.

The programming committee is variously constituted. In some cases, the city manager assumes the full responsibility. In other cases, the city manager, or the mayor, or the selectmen of a town, appoint a special committee of advisers to assist in the process. This committee should normally include the official planning agency and the auditor or budget officer and may include other officials or citizens.

Programming Policy. In approaching the final forecasting process, it becomes necessary to adopt certain basic policies by which to guide the decisions. These policies will relate to the debt situation, tax rate, degree of need that exists for certain public improvements, and general trends in national and international affairs. For instance: if current debt service is high, but requirements for debt retirement will be much less in two or three years, it will be helpful to minimize new capital outlays until the reduced debt requirements release funds that can be available for new improvements without increasing the tax rate. If undue economy in recent years has created a serious lack in certain

facilities or has impaired the proper maintenance of existing structures, larger expenditures may be imperative in the immediate future regardless of other considerations. If a post-emergency situation is seen to be approaching, as at the present time, with possible increases in unemployment to be taken care of, it may be well to delay all possible improvements at present, thus preventing undue competition with defense production activity and conserving opportunities for employment that can be utilized when and if that need develops.

It seems clear that wise expenditure of public funds should take such facts into consideration, but, unless a long-range program for expenditures is developed, it is hardly possible to do so. Municipal expenditures are required to be budgetted for only one year, and general reserves to take care of future trouble have been prohibited. Overlays to take care of uncollected taxes and a reserve to cover unexpected requirements during the current year are regular elements of the annual budget, but long term reserves are prohibited. In a few states, taxes can be assessed for a specified improvement over a few years in advance of construction, so as to have the funds in hand when needed, rather than issue bonds and pay for them, plus interest, in succeeding years.

Improvements in these financial procedures are desirable, but regardless of that, future probabilities can be prepared for only if a long range program is set up, the order of which is based upon these future probabilities in accord with best available judgment.

The Post Emergency Problem. The post emergency problem is the largest imponderable, though ponderous, factor involved in laying out a long-range program at the present time. If we assume a sudden peace followed by prompt demobilization and cancellation of contracts for defense production, we can readily visualize a critical period of readjustment from war production to normal peacetime production characterized by the unemployment experienced, under similar conditions, following the Armistice in 1919. It may be unreasonable to make such assumptions for several reasons. It hardly seems likely that the navy program will be scrapped. The need of a two-ocean navy has been shown, and that policy, it seems fair to assume, will not be changed. The expenditures already committed for the naval expansion will therefore probably continue for a good many years until the program is complete.

To a considerable extent a similar result may probably be expected with the army for many and various reasons related to the policing of the post-war reconstruction period. It may be also assumed that the Federal government is more alive now to the economic repercussions of its policies, than it was twenty years ago. One of the profits of our recent adversity is a somewhat better, if still imperfect understanding, of the effect on the national income of the spending policies of our governments—Federal, state, and local. With this in mind, it may not be unreasonable to expect that the Federal government will handle whatever demobilization is necessary in a manner calculated to harmonize with the speed with which private enterprise can re-absorb its previous employees.

In whatever manner all these factors are handled, there will nevertheless be a transition period full of complexities and re-employment problems. It will be wise to know all possible types of useful employment, especially in those categories paid out of public funds. This knowledge was not available in 1933 when an emergency program was suddenly developed to meet a critical unemployment condition. No state or city had a long-range program of public improvements laid out, from which to cull those most needed and best suited to the emergency relief program. On this account, many relatively unimportant or even useless projects were started, pulled haphazardly out of a list of possible projects hastily collected by public authorities out of their imaginations.

The Federal government is taking active steps to prevent a repetition of such a situation. Long-range programs and capital budgets adopted by our cities and towns furnish the means to this end. A community that has a six-year program of needed public improvements carefully prepared and always on record, brought up to date each year, will never be at a loss what to do, if at any time an emergency program becomes necessary, on a national scale, to take care of abnormal unemployment. Projects scheduled for the following year constitute their next most needed projects and any of them that are suited to the needs of the employment situation can be promptly developed into shape for contracts and put under way. Some projects scheduled later in the program may be better suited to absorb the labor needing relief and can be advanced to immediate construction for this reason, even if less urgent than certain other projects so far as municipal need is concerned. If some of these projects have already

had detailed plans completed, a policy it will be wise to develop, they can be started almost immediately.

This is what is meant by the official references to a "shelf of public works". Water works projects will form a regular and important element on any such "shelf". All improvements will be included, whether they are self-liquidating projects such as water works and other projects of that type, or whether they are paid for out of the tax levy.

The aim of the Federal government, in this activity of the National Resources Planning Board and in the related Public Work Reserve project which is jointly sponsored by the National Resources Planning Board and the Federal Works Agency, is to develop these local six-year programs in every city and town of the country and by the state governments as well. These lists of projects, compiled locally and also in Washington, and kept up to date, there as well as locally through annual revisions, will keep the Federal government continually informed as to the listed worth-while projects of all kinds needed in every state. These can be classified by type, character of labor and materials required, and state and regional distribution, and they can form a firm basis on which to develop any emergency program that may at any time be needed.

Even more important, to my mind, is the improvement this type of programming will develop in regular municipal financial procedure. Current budgets will be based on a reasoned concept of the city's future financial problems; pressure groups for relatively unimportant projects will be discouraged; a long-range policy for debt service and debt reduction will be developed; the needs of the several municipal services will be kept in better balance; and a concept of the municipality's ability to pay, over a period of years, will be more clearly related to the current budget determinations.

All of this constitutes an important new concept in municipal financial procedure. Budget authorizations will continue to be made merely for the current year. The additional five-year forecast involves no commitment, it being merely an indication of future probable requirements by which to gauge wise action in the present. But the procedure constitutes an orderly method of looking ahead, and it is not easy to find any valid arguments against such foresightedness. Perhaps that explains why the procedure is spreading so rapidly. At the

present moment, in New England, capital budget studies have been completed in one state and 3 cities and towns, and are under way in 3 states and 17 cities and towns. It is a beneficial wave that is rapidly covering New England and other sections of the country and that promises much for the future.

Discussion

Frank A. Barbour.* Mr. Parker has presented an interesting paper. He is well qualified to speak on his subject, having been a member of the State Planning Board from its inception from 1935 to 1938, Chairman of its Committee on Public Works, and largely responsible for the special report on "A Policy for Stabilizing Public Expenditures," published in 1938, which led to the proposed legislation—submitted in 1939 but not enacted—entitled "A State Credit Reserve Fund, or Protected Municipal Reserve."

Mr. Parker in his paper, however, makes brief references to public works construction as a counter-cyclical stabilizing factor. His principal theme is the need of organized foresight in state and municipal budgetting—covering both operating and capital expenditures—based on an analysis of past records, projected six years into the future, repeating each year and adjusting the immediate annual budget as conditions indicate to be necessary.

There can be no argument against such rationalized procedure. Certainly any attempt to forecast for six years' population growth, valuation, tax collection, necessary service and revenues therefrom, will improve budgetting practice by making evident the relation of these several controlling factors.

Obviously, successful forecasting of capital outlays by any agency responsible for developing a general municipal budget implies equal foresightedness and advance investigation of long-time needs by those in charge of the various municipal services—and particularly by the water department, in which supply improvements generally require major plant additions, which cannot be constructed piecemeal, and which, therefore, involve immediate large expenditures. At this point, water works men may be inclined to suggest that their departments would be better managed if permitted to operate as a utility free from

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the general budget and the temptation to divert waterworks revenues in order to reduce the tax rate.

Mr. Parker limits the feasibility of longer range budgetting to normal conditions. The question may well be asked as to what may be considered normal conditions. Has the Federal program of public works construction under P.W.A. and W.P.A., or other alphabetic notation, registered such conditions and how can that program, if continued, be fitted into an orderly forecast of municipal financing? In various municipalities, necessary improvements are held up pending guarantee of Federal aid; in others, unjustified expansion of utilities has been induced by the opportunity to obtain the necessary funds from a source not dependent on local taxation. Since such Federal contributions must be met by some form of taxes, it would appear that P.W.A. and W.P.A.—well justified as they may be from a welfare standpoint—are disturbing factors in any scheme of local long-time planning.

And then what of the future; when may we expect normal conditions to return? In the immediate future the great problem is going to be the obtaining of materials absolutely necessary for continued *maintenance* of existing utilities, and the wise operator will put his plant in condition to serve without major additions. Water works men are going to learn that priority is going to affect other things than silk stockings; witness the limitation to maintenance and repairs of Preference Rating Order P-46, recently distributed from the office of the American Water Works Association.

Judging from the economic backwash of the First World War, the years of defense activity will be followed by a considerable period of unemployment and Federal taxes higher than those registered in the Act recently passed, and municipal budgetting will be more concerned in cutting expenditure to the bone than in long-time planning—and this regardless of public convenience as measured by past standards.

The foregoing comments are not an argument against the adoption of the improved budgetting method proposed by Mr. Parker. They simply indicate that its effectiveness for some years to come will be discounted by continued abnormal conditions.

As a sidelight on the budgetting problem, reference may be made to the improvement in Massachusetts municipal finance which has

occurred in recent years—in no small measure due to the good work done by the Director of Accounts in the Department of Corporations and Taxation. Many of us have, at times, differed with his decisions, but there is no question but that the authority delegated to his office has improved municipal budgetting. This control, together with the mandatory requirements of serial payment bonds and the limitation of bond periods for various services as specified in Chapter 40 of the General Laws are in large part responsible for a reduction of some $60,000,000 in the total Massachusetts municipal debt from its high point some years ago.

HILL, NEW HAMPSHIRE—A PLANNED TOWN

BY JOHN L. HAYDEN*

[*Read March 19, 1942.*]

With all the expansion of government and defense housing, Hill, N. H., stands out as unique among planned towns. Hill has re-established an old community in a new location. It has literally traded in its old village for a new one, complete with homes, stores, factory, school and town hall. Moreover, it has combined overall planning with the exercise of personal taste in home design.

In 1938, Federal Flood Control hit the old village of Hill as effectively as a bombing raid. A reservoir was authorized which would obliterate the entire town. This has happened before to other towns. The destruction of war is creating the same problem in thousands of communities all over the world. To some towns, it has meant the death of the community as a civic unit. To the people of Hill it meant an opportunity to re-create a better village in a better location—to preserve historic town traditions going back to 1768—and to hold together a friendly, neighborly village group.

What Hill has done with this opportunity has made it famous all over America. Thousands of tourists have stopped to see the amazing new village of Hill. Hill is the kind of village you dream of living in when you retire—trim little white houses overlooking lake and hills, with all the conveniences that make living easy, located near the heart of New Hampshire's vacation land, with fine fishing and skiing only a short drive away. The author has had an opportunity to watch the growth of Hill, from behind the scenes, through the work of his firm as engineering consultants to the town.

Faults of Old Hill Have Been Avoided. The old village of Hill on the Pemigewasset River with its ancient houses was strung along two miles of Highway 3A between Franklin and Bristol. Hill was a picturesque town, though more because of its age than by design. Like most old towns, it just grew. The main street probably followed a hunters' or traders' trail to the north, but once the pioneers located it, the sum total of town planning for two centuries was completed.

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In 1930, the township consisted of 120 families, of whom three-quarters lived in the village. Its "ribbon" plan is typical of most smaller towns built during the horse era. The old town had no center, civic or otherwise, on which to focus. Stores and commercial development squatting between home and home were an intrusion on the beauty of the town. These faults have been avoided in the new Hill.

Flood Control Dooms Old Hill. Old Hill was doomed when a dam was authorized at Franklin Falls to control the Pemigewasset, a tributary of the Merrimack. In summer, the quiet Pemigewasset is one of New England's most beautiful rivers. In spring, melting snows of central New Hampshire and the White Mountains often convert it into a raging torrent which pours into the Merrimack and inundates downstream cities. For some years prior to 1938, the Federal Government had studied possible flood control measures for the New England rivers, particularly the Connecticut and Merrimack drainage areas. The damaging floods of 1936 and 1938 made the project appear an immediate economic necessity.

Government studies showed that the principal unit of a system of reservoirs to control floods in the Merrimack valley should be located on the Pemigewasset River, 2.8 miles above its confluence with the Winnepesaukee River and 2 miles north of Franklin, N. H.

Reservoir Controls 1,000 Square Miles of Drainage Area. Construction of the dam was started during the latter part of 1939. The project will be completed during the late summer of 1942. The detention reservoir has a tributary drainage area of 1,000 sq. miles, including a large part of Grafton County, and a considerable proportion of the White Mountain area west of the Saco River watershed. It covers an area of 2,950 acres, and has a storage capacity of 170,000 acre-ft., equivalent to 3.2 in. of run-off.

The dam is of rolled earth fill with dump rock shell. It is approximately 1,700 ft. long with a maximum height of about 40 ft. The gross volume of fill in place is 3,500,000 cu. yd. The spillway is designed for 210,000 c.f.s., or nearly three times the maximum flow on record, estimated at 76,000 c.f.s. in 1936.

When the dam was proposed, it was evident that the surrounding community would be little affected. Old Hill, however, was practically in the middle of the projected reservoir. The elevation of the town was 342 ft. above sea level; the flood crest of the dam was 395 ft.

This would flood the entire village with 50 ft. of water—enough to completely cover most of the buildings.

Hill Votes to Rebuild the Village. When the people of Hill learned that the destruction of their village was inevitable, they faced three alternatives: They might just let the old town die, as so many other doomed towns have done, each family taking its share of Federal compensation and settling elsewhere; they might build a new Hill on the hit-or-miss pattern, with all the faults of the old, but without its charm; and the community might coöperate to build a new model village planned for safe, comfortable, economical living in a motorized age.

Town officials turned to the New Hampshire State Planning and Development Commission. After considerable study, Frederick P. Clark, Director of the Commission, presented his report at a Town Meeting in December, 1939. He expressed his belief that a soundly planned community was the only kind Hill could afford. He made it clear that this was Hill's own undertaking. He warned of the many difficulties, financial and otherwise, that would have to be overcome. When a vote was called for, it was unanimous to go ahead with the planned village.

The basic plan of the re-created Hill was prepared by the Commission who advised the town to engage competent architectural and engineering consultants to handle the public buildings and public utilities. Our firm was retained to plan and supervise the construction of the water works and all other public utilities.

Hill Approves its Town Plan. After Hill had decided to go ahead with the new planned town, the next step was to show the townspeople what kind of a village they would get. Persuading 30 or 40 separate families to approve a village plan—no matter how well laid out—is a real job of coöperative selling.

Because many had no experience with blueprints, perspective drawings and scale models were used to show everyone just what the new village would look like. These were explained and re-explained until everyone concerned understood them and fully approved. Hill thus became uniquely the people's own town. It was not something imposed on them by outsiders but was the result of their voluntary choice. Because of this, community spirit has grown to an aggressive force which seems to assure Hill's continued success. It is a com-

pliment to the thoroughness of the Commission's experts and the consultants involved, as well as to the understanding and coöperative spirit of the townspeople, that the original plans have been followed practically without change.

A Village Designed for a Motor Age. The Commission's plans or an airplane view of completed Hill show a new kind of village, designed to meet the needs of a motor age. See Figures 1 to 3.

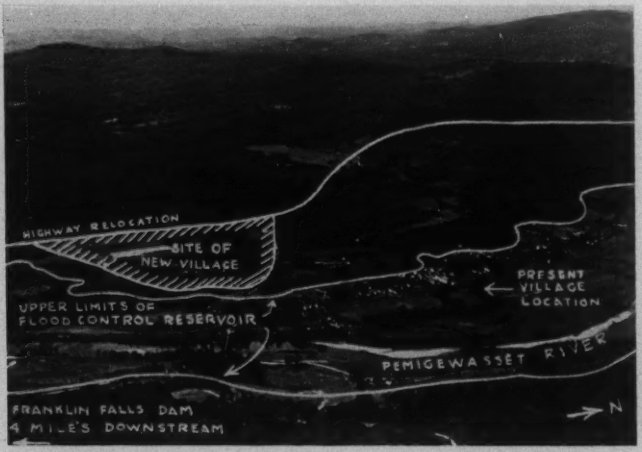

FIG. 1—WHITE LINES SHOW HOW THE NEW FLOOD CONTROL RESERVOIR WILL ENGULF THE TOWN OF OLD HILL. THE NEW VILLAGE, ON HIGH LAND, WILL BE ON THE SHORE OF THE RESERVOIR, AFFORDING SPLENDID VIEWS OF THE LAKE AND HILLS.

Though the town is located on the new Route 3A, a through traffic artery to vacation country, there are no homes on the main highway. The town has taken care that there never will be any. A greenbelt on both sides of the highway is owned by the town and zoned as a permanent building-free area.

The entire village is located on one side of the highway. There are no dangerous pedestrian or automobile crossings. Everyone lives comfortably away from highway traffic—far from the noise, smells,

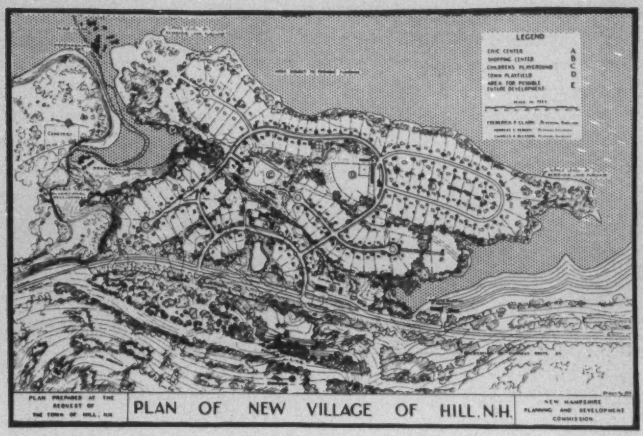
LEGEND
CIVIC CENTER
SHOPPING CENTER
CHILDREN'S PLAYGROUND
TOWN PLAYFIELD
AREA FOR POSSIBLE FUTURE DEVELOPMENT
A B C D E
PLAN PREPARED AT THE REQUEST OF THE TOWN OF HILL, N.H.
PLAN OF NEW VILLAGE OF HILL, N.H.
NEW HAMPSHIRE PLANNING AND DEVELOPMENT COMMISSION

FIG. 2.

and danger. People can visit neighbors, shop, go to church or town meeting, or take pleasant walks without coming near the main road. Children can go to school and to their playground without danger from speeding motorists.

Village Focuses on Civic Center. The new village focuses on the civic center, with a town hall and grade school already built, and a union church planned to serve the parishioners of the two churches in old Hill. These buildings are reached from the main highway by a semi-circular main road which curves in to the civic center, then back to the highway. The residential district is on high ground behind the civic center.

Passing motorists will remember Hill by their glimpse of the white colonial town hall reflected in the water of a natural pond beside the highway. The glass cupola of the town hall is illuminated at night and is a landmark for miles around. The pond is attractively landscaped with trees and grass. Few villages in America present such an attractive appearance to visitors or have a civic center so convenient to the homes in the village.

Shopping Center is Convenient to Town and to Visitors. The

FIG. 3—AIRPLANE VIEW OF THE NEW HILL WITH RESIDENTIAL STREET IN THE FOREGROUND. IN THE MIDDLE IS THE CIVIC CENTER WITH TOWN HALL AND SCHOOL ON CURVING MAIN STREET. THE THROUGH HIGHWAY IS SHOWN AT THE LEFT.

shopping center is located on a bypass near the highway, on the south side of the village. The stores are housed in an attractive colonial arcade which harmonizes with the town hall and the overall village plan. Only one store of a kind is permitted, and new stores must be approved by the town before they can occupy space in the arcade. Hill is thus protected against the hodgepodge of commercial buildings that make so many town centers unsightly.

Unlike village stores built during the horse era, Hill's shopping arcade has wide parking space, away from high speed traffic. This is a convenience to townspeople who do not have to enter or cross the main highway to shop. A gas station on this bypass serves northbound traffic, and another on the opposite side of the highway serves southbound. This increases local business, and also reduces the need for cars to cross opposing lines of traffic.

Hill's Industry is Needle Manufacture. While old Hill had several small manufacturing plants, its chief units were the needle factory and the crutch factory owned by Edward Amsden, a selectman of Hill. Mr. Amsden's foresight and energy contributed much to the success of the new Hill. His crutch factory was situated on high enough ground so that it could remain in its old location. The needle factory has been moved into a new building on the main highway at some distance from the village center, and not far from the shopping arcade. Many of the townspeople are employed in these two plants which are now operating at capacity on war orders.

With these industries, Hill is a splendid example of the combination manufacturing and farming village that many authorities have advocated as one solution of our peace-time industrial problem. While the half-acre lots in Hill are not farms, they are large enough for subsistence gardens. Those who wish can supplement their incomes by raising vegetables for the table and for preserving. Several families have full-sized farms close by the village.

Recreational Areas Provided for All Age Groups. Unlike old Hill, which had virtually no public play spaces, the new Hill takes full advantage of its location in the heart of a vacation state. Approximately half the village is publicly owned, giving a feeling of spaciousness, and guaranteeing that the village can never become overcrowded. Public paths connect all village areas. Large recreational areas are provided for all age groups, adults as well as children. The children's playfield is directly accessible from the grade school. No street need be crossed in going from one to the other. Among its attractive features are a pole-roofed shelter, a rock-lined pool, and well-equipped game courts.

Homes are Individually Built. On a sightly knoll behind the Civic Center is the residential section. The houses, each on a half acre or more of land, are located on curving roads planned to fit the topography, and to provide attractive views of the reservoir and the White Mountain foothills beyond.

Hill is the exact opposite of a mass-manufactured housing project. The people have been able to express their own individuality in their homes. Each family has built the size and kind of home it wants, subject only to loose deed restrictions such as minimum cost and colonial design. Some were architect designed, others were built

from stock plans; four or five were moved from the old village. No two houses are alike, although they all are tied together by their colonial design.

The new houses are well built and well suited to modern family sizes and habits. A comparison between the houses of old Hill and the new village is an interesting commentary on changing social habits. Many of the old houses were large enough for the big families of the older days. They had large kitchens and barns, and during bitter New England winters, were drafty and hard to heat. Most of the houses in the new village are small and trim, suited to today's smaller families, and far easier to heat and keep up. Only a few cost as little as the $2,000 minimum. The average cost is around $4,000 for the house and lot. Most are modernly equipped throughout, with landscaping well started.

Land Speculation Was Prevented. Naturally, a complete new village could not be built without many difficulties, financial and otherwise. But Yankee ingenuity, aided by coöperation from state and financial authorities overcame every hurdle. As an example, you might wonder how Hill could prevent real estate speculators from buying up all likely village locations, for exhorbitant profits. The town fathers anticipated this difficulty by a counter attack. When the speculators arrived, they found three leading citizens had beaten them to it. They had already secured options on all available land and formed a non-profit Improvement Association to handle sales. Through their foresight, buyers have been able to secure building lots for around $150 to $250, with the privilege of getting their money back if they do not build within a year.

Economies in Planning and Construction. The town of Hill, like the home owners of the old village, is receiving compensation from the Federal Government for abandoned roads, bridges, public buildings and utilities, including the old water works system. Still, funds were limited, and creation of the new village called for many ingenious short cuts in planning and economies in building.

Street layout was arranged with the contours of the land. Only two very minor cuts and fills were required. Length of streets was held down to a total of 1¼ miles as compared with 2½ miles in old Hill. Public utilities such as water, sewer and electrical conduits

are laid under a grass strip between sidewalk and pavement, eliminating ripping up pavement for maintenance or repairs.

Cost of public buildings had to be kept low, yet more space and improved facilities were required. The new town hall, for example, is commodious, and modern in every detail. On the first floor are offices, hall, and library. In the basement, the fire engine and maintenance apparatus share the garage, and there is a kitchen and dining hall where many a town get-together and supper have already been held. Construction is typical wood frame on concrete foundation, with wooden roof trusses. Interior walls are of unfinished fibre board, with a pine wainscot in the auditorium. Roof is of asphalt shingles. The total construction cost was held to under $16,000.

Water Works System Planned to Give Greatest Value for Money Spent. Like public buildings, roads, recreation facilities and homes, the water works system and other public utilities were planned for the new village on the same principle of getting the greatest value for the money spent.

The old town had a gravity system, supplied by a small booster pump. It had as its source a pond on Needle Shop Brook. The distribution system consisted of a maze of privately owned water systems finally brought together in one town-owned system. The pipe sizes ranged from 2 to 12 in. Every conceivable kind of pipe was used, including wood-stave pipe and pipe made of logs with the core hewn out leaving a shell approximately 2 in. thick.

Obviously, this old distribution system could not be saved, and because it was not found economically feasible to use the old source of supply for the new town, the entire old water works system was abandoned.

The planning problem of the new water works system was complicated since no one knew how many people would go to the new village. It was finally decided to design the new system for a population of 800. This provided ample reserve capacity for any growth that could be expected, and with an additional well, the new system would have five times the capacity of the old.

Well and Pumping Equipment. The water supply source is a gravel-packed well located about one mile northwest of the center of the village. It is approximately 40 ft. deep, with a 16-in. inner casing and a shutter-type screen 12 ft. long. Pumping equipment includes a

multi-stage, deep well, turbine-type pump of 115 g.p.m. capacity against a 220 ft. head. The pump is driven by a 10-h.p., 220-volt, electric motor, with a gasoline engine for standby motor power. The pumps are automatically operated from pressure-switches, mounted on a control panel, with indicators for determination of consumption of water, pressure, height of water in the stand-pipe, and time clock.

The pump house is constructed with a concrete foundation, brick structure, and a concrete slab with roof scuttle for removing equipment.

Construction of Standpipe Complicated by Difficult Terrain. The standpipe is located on the side of Huse Mountain, across the highway from the village. It is of welded steel construction, 36 ft. high by 36 ft. in diameter, with a capacity of 274,000 gal. Every steel plate and all concrete for the foundation had to be carried up the sheer, wooded side of Huse Mountain in winter, greatly increasing the difficulties of construction. A bulldozer was used to slide the 20-ft. steel plates over the snow. The trail was so rough and steep that one sheet got away and slid down the mountainside. Fortunately, means were found in Concord for re-rolling.

Concrete was mixed at the bottom of the mountain, and carried up the steep trail in a bucket-type bulldozer—one of the only two of its type in New England.

Distribution System. The water distribution system consists of about 3,000 ft. of 8-in., and 12,000 ft. of 12-in. transite pipe. Hydrants are set at 350-ft. intervals to give complete fire protection for the entire town.

Cost of Water Works. The town issued twenty year bonds in the amount of $40,000 to finance the construction of the water works system. Two separate contracts were let for the system. Contract one, including the distribution system and standpipe, cost $28,684. Contract two for the gravel packed well and pumping station, cost $10,260, making the total cost $38,944.

A Worth-While Town to Visit. If you visit Hill, you will find a combination you never saw before—a 1942 model of town planning, yet retaining all the best characteristics of a typical New England village.

CLEANING, STERILIZING, AND INCORPORATING THE AMOSKEAG MILLS WATER SYSTEM INTO THE MANCHESTER, N. H., CITY SYSTEM

BY PERCY A. SHAW*

[*Read May 21, 1942.*]

The Amoskeag Manufacturing Company. The Amoskeag Manufacturing Company was a cotton and woolen manufacturing company situated on both banks of the Merrimack River in Manchester, N. H. It was the largest cotton mill in the world. The plant extended along the river, on both sides, for a distance of about one and a quarter miles. The buildings covered an area of about 100 acres on the East side of the river and 70 acres on the west side of the river. The area was closely covered by buildings, two long canals, railroad sidings, running the full length of the yard on both sides of the river, and the Company's own streets. Floor space in the buildings had an area of about eight million square feet. The Company had its own hydro-electric and steam-generating plants and did its own finishing, bleaching and dyeing. The first mill in Manchester that carried the name Amoskeag was established about 1810.

The Amoskeag Water System. This great mill property also had its own water supply, taking water from the Merrimack River above the dam and from the Upper Canal. There were four large-capacity pumping stations; one was used for normal pumping into the system, the other three for fire service. Water was pumped direct into the system with the excess going into an 11-m.g. storage reservoir on the hill east of the plant. There were in the plant also two 5-m.g.d. rapid sand filters used for clarifying water for process purposes.

The water piping system included over 12 miles of mains from 4 to 24 in. in diameter. Included in the system were several miles of 14-in. mains running through the Company's streets up and down the river. Before the 1936 flood, there were several ties across the river on bridges. After the flood, the only connection was a 20-in. main

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under the Merrimack River, near the center of the property, at Bridge Street. Only drinking water was taken from the City mains and this was piped through the mills through very long small-diameter wrought-iron pipes.

The Amoskeag system was connected to the City supply for emergency purposes at several points. There were two 14-in. and one 8-in. cross-connections; these were protected by double bronze check valves. The Mill system pressure was about 20 lb. per sq. in. less than that in the city's low-pressure system with which the mill system was connected.

Disposal of Amoskeag Property. In 1936, this huge manufacturing company was forced into bankruptcy. When it appeared that the machinery would be sold for junk and many of the buildings torn down, robbing the city of Manchester of its principal source of income, local business men and banks assumed the risk of purchasing the entire property. The corporation set up to accomplish this undertaking is known as Amoskeag Industries Incorporated. Carrying out their purpose to act for the best interest of the city, and to keep down expenses, Amoskeag Industries arranged with the Manchester Water Works to take over the Amoskeag Water System and supply water in the mill area. By so doing, they avoided pumping and other operating expenses, obtained a safe and cheap water supply for the businesses which then occupied and which they hoped and believed would occupy the mills, and also obtained adequate fire protection for the mill area.

In acquiring this additional water system, the Manchester City Water Works obtained the possibility of a considerable increase in business, eliminated cross-connections with the river water, and at the same time carried out its normal function of supplying water and fire protection to an important area of the city. The Manchester Water Works took over the operation and maintenance of all outside piping, including a good deal of piping not suitable for inclusion in an integrated system. One item in the City's agreement with the Amoskeag Industries was to add a step in its water rates, making the price for water used in excess of 300,000 cu. ft. per quarter 5¢ per 100 cu. ft. The first 100,000 cu. ft. is 10¢ per 100 cu. ft. and the next 200,000 cu. ft. is 7¢ per 100 cu ft.

Problems Involved in Taking Over System. There were nu-

merous problems involved in supplying water to this system, which had been in use, carrying river water, for more than 70 years. We did not have to worry about having a sufficient supply of water from our source, Lake Massabesic, or about adequate mains and reservoir capacity; but the Mill System had to be more adequately connected with our system in order to give satisfactory fire protection. The Amoskeag Industries in 1938, when we were planning to take over, was pumping about a million gallons of water per day into the mill area, although the area was less than half occupied. This indicated a very large amount of waste and leakage, which had to be found and stopped. The best plans available were those of the Fire Underwriters; even these were general and incomplete, and there were no plans of inside piping. This meant that we had to survey the pipe system outside and in, which, when you consider that there were 180 acres of floor space was something of a job. It was also necessary to separate mill-use piping from fire-service piping in many places, and to so rearrange piping that use of water could be metered to the different companies occupying the buildings. Planning for this piping was done by the Water Works. Plans were submitted to the customers and the piping done by them. Meters from ¾-in. up to 8-in. and 12-in. fire-service meters with compound by-pass were installed.

But our most important problem was cleaning and sterilizing these old mains and the miles of mill piping. There was some question as to whether this could be done or not. An estimate of cost for new mains showed an unwarrantedly high cost, considering the prospects for business as they were at that time. Repiping the mills was out of the question.

Interconnection with Manchester System. Problems of interconnection with the City system were solved in the following manner. The 11-m.g. equalization and settling reservoir was abandoned. This seemed wasteful to many; but it was 45 ft. in elevation below the City's low-pressure reservoir, and its use would have required setting up a third pressure level which would have seriously complicated our operations. The fact that we already had distribution storage of 36 m.g. in our high- and low-pressure reservoirs also had a bearing on this question.

The first step in connecting the two systems was the construction of a 16-in. main 1283 ft. from the 14-in. main in Elm Street to connect

with three 14-in. mains running parallel to the river in company streets on the east side of the yard. This main was run down Stark Street, crossed under the main line of the Boston and Maine Railroad, under two railroad sidings, and through two canals. When this 16-in. main was completed, gates were shut at the points of cross-connection and we were ready to feed the Mill System with City water through the 16-in. main. An 8-in. meter was set in a by-pass to this main at Canal Street to measure the flow into the yard and help us in our reduction of waste and leakage.

The 24-in. pumping main to the Amoskeag Reservoir was later connected into our high-pressure system. Connections of the yard system were made to our high-pressure system through 12-in. and 16-in. pressure-reducing valves. These were set to supply water to the Amoskeag System, and later our entire low-pressure system, with a 10-lb. per sq. in. drop in pressure.

Mains in company streets and between groups of buildings were accepted as city, or public mains; about eight miles of such piping was accepted for incorporation into our system. The remainder of the piping, supplying single buildings or groups of buildings was considered as private, or mill piping. A considerable length of old piping was abandoned, and some new connections between mains were necessary. The hydrants in the yard were nearly all single-hose connection hydrants. There were 360 of these hydrants of which the city took over 163. Twenty-seven were eliminated and 170 allocated to certain building areas as private hydrants.

Location Surveys and Plans. While the 16-in. main was being constructed, three parties started location surveys of the pipe system inside and outside the buildings. Large-scale drawings were made of each building, all of the piping traced, located and drawn on the plans. Such a jumble of city water, mill-use, sprinkler, steam, and air piping no one ever saw outside an old cotton mill. Both inside and outside piping systems had just "growed up" like Topsy. We are still not sure where some of the yard piping is. In making connections to it, we have found both horizontal and vertical offsets, put in to avoid other piping and similar obstacles. An estimate, based on measurements made in typical buildings, showed that there were over 150 miles of inside water piping varying from 8 to 1 in. in diameter; this includes the sprinkler system.

Cleaning Old Mains. The next job on the program was cleaning the 10 miles of mains kept in use and the more than 150 miles of inside piping. This pipe had always carried river water and was partially filled with silt. At all times when cutting into this system and when cleaning it, our operations were handicapped by the fact that many mill areas were in use and their requirements had to be considered.

The question of using mechanical cleaning devices naturally came up; but due to the fact that locations were somewhat indefinite and offsets and bends were many and not located, we felt that the use of mechanical cleaning would require too much digging for "go devils", and that mechanical cleaning should not be used unless the system could be cleaned in no other way.

We had 11 m.g. of water on hand in the Amoskeag Reservoir, and we used nearly all of it in flushing out the main pipe system through the hydrants. Several hydrants were opened at a time in order to get a scouring velocity in the mains. The visual results of this first flushing were large quantities of mud and tubercles. When this flushing was over, no river water was again put into the system.

We then flushed the entire system using city water. Wherever possible, this flushing was done in the direction opposite to that when river water was used; with the city water we also had 20 lb. per sq. in. more pressure. This second flushing produced little mud, but large quantities of coarse material. Fire-flow tests indicated that the mains were comparatively clean: later, rapid travel of chloramines attested to the freedom of the mains from vegetable or other absorptive matter.

Disinfection. With the outside piping cleaned, or at least well rinsed, we were ready to disinfect it. The entire mill system on both sides of the river was now fed through our new 16-in. line connected at about the center of the system on the east side. All of the water normally went through the 8-in. fire-service meter, arrangements having been made to have the main valves opened in case of fire. Over this main was constructed a small building to house the chlorinating apparatus. This equipment consisted of two electrically-operated "Proportioneers" pumps, one for chlorine and one for ammonia. The solutions were mixed to the desired strength in 20-gal. crocks

and fed from them. A blind man could have found this chemical plant if he got within 150 ft. of it.

For our chlorine we used a 12½% sodium hypochlorite solution and for ammonia 29% B. E. ammonia solution. We used special rubber tubing for connections between the solution tanks and pumps, and copper tubing for discharge into the main. The copper worked all right for a temporary hook-up but showed corrosion. Taps in the main were 8 ft. apart with the chlorine going in ahead of the ammonia. The plant was operated 24 hours per day from the time it was started until the completion of the preliminary disinfection program. Due to the continued program of drawing this highly chlorinated water into the mains and mill piping, it was necessary that this chlorinating process should be a continuous operation from the time of starting until the time of completion. The proportion used throughout the disinfecting program was two parts chlorine to one part ammonia. Chloramines were used instead of chlorine alone as we anticipated difficulty in getting plain chlorine residuals through the entire mill system.

We planned to vary dosage with the flow, which averaged about 1 m.g.d. As the water was not used for drinking, we found we could use a constant quantity of chemicals on week days, causing the residuals to vary from double the calculated strength of 1.0 p.p.m. at night, to about one-half strength or 0.5 p.p.m. at peak flows. A stronger solution might have worked more rapidly but could not be used on account of the industrial use of the chlorinated water. Results proved that the amount of chloramines used was sufficient.

Our survey crews now became disinfecting crews. Hydrants were opened to supplement mill use and draw chlorinated water through the mains more rapidly. Chlorine absorption was not nearly as high as we had anticipated, and residuals traveled through the mains perhaps five times as rapidly as we had expected. Probably this was due to the mains being cleaner than we had believed. We had thought it possible that the chlorinating plant would have to be moved to several places in the system to reduce the length of travel.

With a daily average use of 20 gal. of 12½% solution of hypochlorite and 4 gal. of 29% B. E. ammonia and a daily flow of 1 m.g.d., we obtained residuals varying from 0.15 to 1.0 p.p.m., the residual varying with distance from the chlorine plant. The most remote

point from the plant was approximately a mile distant through pipe sizes varying from 6 to 20 in. Forty-eight hours from the time of starting, residuals of 0.15 p.p.m. were obtained at this point. We also found by test that, after shutting off sections that had residuals in them, a high percentage of residual remained at the end of a 30-minute interval and that there was a trace at the end of an hour.

After chlorine residuals had been obtained at all hydrants, work was started on the 800,000 lineal feet of inside piping. Much of this was 4-in., 6-in., and 8-in. sprinkler and industrial piping. Mill use, sprinkler, and hose pipe lines were bled until a chlorine residual was obtained at every dead end. Sprinkler lines were the greatest problem, because the last sprinkler head on each run had to be removed, a hose connected, and the water flushed out of windows. Fire-service lines and sprinkler systems were disinfected as a safeguard since, in the future, mill or domestic lines might possibly be connected to them.

The stagnant water in the fire-service lines was the color of ink but rapidly cleared on flushing. It should be remembered that the high chlorine residuals were continued in the main lines throughout the time this process was going on, or for about one month. A total of 470 gal. of 12½% hypochlorite and 116 gal. of 29% B. E. ammonia were used for this intial sterilization. The approximate number of tests for residual chlorine made through the system including yard mains, fire service, and mill-use was about 2000.

We proceeded with more confidence on this work, because in the fall of 1938 we had cleaned and disinfected, by the same methods, 1600 ft. of main that we had added to our system on the west side of the river at that time. Tests on this main after flushing and before chlorinating showed the water to be practically free of *B. coli*. After disinfecting, the water was free of *B. coli* both 24 hours after disinfecting and two weeks later.

Tests. As the work of disinfecting proceeded, water drawn from the hydrants, taps, and sprinkler heads was sent to the New Hampshire State Board of Health for testing. Water from the mains and mill-use taps was practically always free of the coli-aerogenes group; occasional samples only containing these bacteria in 10-ml. quantities. Other bacteria were usually high in the samples from the mill piping. The poorest samples were from hose lines connected to the sprinkler

system. These lines had been used to carry river water shortly before chlorinating.

In spite of fairly good results, we were not satisfied with our first chlorination; and as we had left our plant ready for just such possible use, we proceeded again to disinfect the system. All of the lines showing contamination in the previous tests were reflushed until residuals were again obtained. A total of 270 gal. of hypochlorite and 116 gal. of ammonia was used for this second process. Samples were again taken, and tabulations of the final analyses showed that out of 105 total samples taken only 6 gave positive reactions; of these only 2 showed positive reaction in 1-ml. samples, both of these being from sprinkler mains.

Our procedure may be summarized as follows: we flushed all outside piping, first with river water, and then with city water, using high velocities. We maintained in this "yard" piping a concentration of chloramines showing a chlorine residual varying from 0.15 to 1.0 p.p.m., for a period of about six weeks. We flushed all inside mill-use and sprinkler system piping until a chlorine residual was obtained. All lines showing any *E. coli* were reflushed and a chlorine residual again obtained. Drinking water standards were obtained in all yard and mill-use piping before the system was declared fit for general use.

In order to have added assurance that we had accomplished our purpose, samples from the contaminated locations were sent to the firm of Weston and Sampson, Consulting Engineers, Boston, Mass., as well as to the State Board of Health. The judgment of Weston and Sampson was that we would have an entirely safe supply.

During the two and one half years since our customers in the mill yard were notified that the water was fit for drinking, we have had no difficulty or ill effects of any kind. The greater portion of the mill buildings is occupied, and employment again has reached a high figure. The rehabilitation of this property has meant a great deal to the City of Manchester, and the men who had the courage to accept the burden and risk of its revival deserve a great deal of credit. Throughout the period of reconstruction and disinfection, we had most excellent coöperation not only from Amoskeag Industries, but from the many occupants of the mill district. The work of incorporating this industrial water system into the City Water Works was in the general charge of the writer and his assistant, Mr. James A.

Sweeney. All cleaning and chlorinating were under the charge of Mr. Clarence E. Ferry from whose report to the Water Works much of this information is taken. The enormous detail of piping plans was in the patient hands of Mr. Charles Ringenwald. From the beginning we had both the encouragement and coöperation of Mr. Charles D. Howard, Director of Chemistry and Sanitation, and Mr. Leonard Trager, Sanitary Engineer, of the New Hampshire State Board of Health.

PUBLIC WATER SUPPLY IN THE CIVILIAN DEFENSE PROGRAM

BY R. E. TARBETT*

[*Read April 23, 1942.*]

Since this is a general meeting attended by doctors, engineers, and others connected with or interested in public health, I will discuss the subject of Public Water Supply in the Civilian Defense Program in rather general terms at first and then, for the benefit of water works men present, in more detail particularly as it applies to certain essential features in planning and organization. It is not my intention to discuss or advise how water works should be operated, mains repaired, or water treated during an air raid. I doubt that I could bring to water works officials information that would be of great value to them on those subjects.

We are preparing for a performance in the great theater of war. In this performance water works should be one of the principal actors. Is it cast as a principal and not in a minor role; does it thoroughly know its part; has it rehearsed its part with the entire cast so that if and when the opening night comes the show will go on smoothly?

Remember it will be a big audience—our enemies and our friends. We will receive both applause and hisses. We must be sure that the applause is from our friends and not our enemies. The length of time the show will run may depend upon the opening performance. The better the performance the shorter the run.

First let us understand clearly that this country is organized to fight an offensive war. All of the resources, both military and civil, are being devoted to this end. This means that material, equipment, and supplies necessary for normal operations, let alone emergency operations, must be curtailed, and military defense for our cities likewise curtailed. We must, therefore, plan to take whatever comes and handle it in the best way possible. In this connection, I wish to quote from a speech made by Director Landis March 19, 1942:

"Every student of American history knows Stonewall Jackson's Valley Cam-

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paign, and remembers how his threat to the city of Washington drew Federal troops away from the fighting front in Virginia. Insofar as our powers go as civilians we cannot permit the enemy today to pursue that tactic, and by our fears of what may happen to the home front to divert men and guns and planes from the fighting front abroad. If that tactic is pursued by the enemy, we must be prepared as civilians to stand and take it with the least possible interruption to the fighting economy that we have now built. As civilian defenders we must thus not only organize ourselves to protect ourselves but build so strongly behind the battle line that to the men at the front will echo the knowledge that offense can freely be theirs for defense is firmly in hand."

Naturally we hope that no city in this country will have to suffer the experience of a bombing, but don't let wishful thinking lead to a state of mind that "It can't happen here." Better let this thinking be along the lines that it will happen here. That it will happen is perhaps believed more firmly in this section than in many others. This is evident from the fact that you are somewhat further along in the civilian or passive defense program than are many other sections of the country. Nevertheless I believe you still have much to do in effecting a smooth running organization that will be able to cope efficiently with any emergency that may arise.

For efficient operation of a municipal organization, the various activities that are carried on through regularly constituted agencies must be properly integrated. If this is necessary in normal times, it becomes much more necessary in times of emergency. In preparation for a possible bombing some new activities are being developed and duties of regular agencies expanded. In your planning are you considering how these activities should be created or expanded, the relationship of each to the other, the expansion of existing constituted agencies rather than the creation of new ones, and the like? It should not be forgotten that regularly constituted agencies are charged by law with certain duties and must continue to carry out these duties during emergencies as well as under normal conditions.

Too often the civilian defense planners are carried away in their enthusiasm to the extent that they forget that their defense program should be developed upon and around the existing regularly constituted agencies. They appear to consider that civilian defense is something new and that all activities must be built from the ground up. I hope you are not making this mistake. There is a certain amount of excitement and glamour connected with organizing, train-

ing, and preparing for emergency activities. The first bomb to fall will in all probability explode a great deal of this. The actual work will be hard, dirty, and dangerous.

Thus far I have said little about water supply which is, of course, one of the activities that is very important from the civilian defense standpoint in any community. To this audience I need not stress the importance of maintaining at all times an adequate supply of water for fire fighting and domestic use and at the same time a safe water for human consumption. Have you stressed the importance of water supply to your Commander, Citizens Defense Corps? To him it may mean only shutting off a few valves which he thinks anyone can do, or repairing a few broken mains which can also be accomplished by repair squads set up under his direction. I say have you stressed the importance of the public water supply in the defense program to your director, because my observations have been that sometimes too little consideration has been given to it in the general planning for defense and that a rather vague idea exists in the minds of some as to what is involved in maintaining the supply.

Water works and health officials should not be hesitant, in fact they should be insistent in demanding that proper consideration be given in the over-all planning to this very essential activity; and that it is not an activity for untrained men to play with but must be carried on under the regular water department with personnel trained under its direction.

A little thought on the subject of public water supply will lead to the conclusion that the whole civilian defense program is based on the maintenance of the supply. I can go back into ancient history to show that control or destruction of the water supply by the enemy was more effective than other military operations. I say I can go back into ancient history, but recent occurrences are too fresh in all our minds to require any historical references. Whether it be capture, or destruction, or both matters little so far as the defenders of a city are concerned.

We have often compared a community to a human being and have referred to the water supply as the life blood of the community. In the case of an air raid, the analogy between a community and an individual is rather striking, because somewhat similar procedures, only under different names, are followed. The water distribution

system of a city is similar to the circulatory system of the human body and has its main arteries and its venous system. When a bombing occurs the medical first aid squad is immediately dispatched to the scene of the incident. Likewise a water first aid squad is also dispatched. These first aid squads, both medical and water, do much the same to their patients. They attend the most serious first, giving such aid as possible, pending proper treatment later. It may be a tourniquet in the case of a human being, and the closing of a main water artery in the case of water. But a tourniquet cannot remain on long, neither can a control valve on an artery of a water system remain closed for long without danger to the patient. The only difference is in time, one being a few minutes, the other a few hours, or at the most a very few days. Regardless of the extent of the injury, the human patient generally receives a shot of anti-tetanus serum. Likewise a shot of chlorine is necessary to our water supply patient. We can carry the analogy still further. Blood banks are being established in order that blood for transfusion purposes may be readily available. Our water works patient may also have lost too much of the liquid that flows in its veins and may, therefore, need a transfusion from some auxiliary source. Blood for transfusion must be prepared in advance, auxiliary sources of water must also be arranged for in advance.

We must prepare in the water works field just as in the medical field if the results of a bombing are to be met and our citizens individually and collectively are to receive the treatment that they have every right to expect.

In the disasters that have occurred in the past, water works officials have been quick to aid their neighbors. In a disaster due to an air raid you will still find this same willingness to aid as in other disasters, but it will be difficult to do. For this reason, prior planning for mutual aid is desirable, in order that this aid may be provided promptly and without confusion. To us, a bombing is a new type of disaster and will require somewhat different planning from that to which we are accustomed. Under the mutual aid scheme, group planning is provided for, and this appears to be a very desirable procedure. Priorities in obtaining supplies and materials bother us and probably will until the end of the war. With a mutual aid plan, we

have a pooling of materials, supplies, and equipment which can be promptly made available where and when needed.

This mutual aid plan for water works as it is being developed in the various states is not new in New England, since it originated in Massachusetts. As you all know, this plan applies to groups of communities but should, if carried to its logical conclusion, include assistance to the local water works and defense officials in their planning, since the job of maintaining the water supply of a community is after all the duty of the local officials.

I am not worried about local water works officials and engineers, so far as technical ability is concerned. However, I am not sure that in all cases they have a thorough understanding of the over-all civilian protection program and how their services should be integrated into the general pattern of defense in the local community. Unless this is done, these officials will find themselves working at a disadvantage or unable to function at all when the time for action arrives.

I know that water works officials generally have been taking those steps necessary to protect their properties from any action by subversive groups, and I need not discuss this part of the program. I do feel that water works officials have not given sufficient thought to what could probably happen even with a token bombing. In one area where this question has been considered, it has been assumed that a token raid would involve at least forty bombers, that at least 20% of the bombs would fracture mains and that 80 breaks would occur within a very limited time, one for each 37 miles of mains. On this assumption, the officials in this area have prepared their plans.

An article by Norman J. Howard entitled Defense of Water Supply Works, in the American Water Works Association Journal of September 19, 1941, states:

> "In one city, which has had fairly effective protection against air attacks, breaks in the distribution system have occurred at the rate of 1 per 100 miles of main per day, over a period of several months. In another city, where the defense against air attacks was very inferior, there were attacks of such intensity, over a two-day period, that water mains were broken at the rate of 1 break per linear mile per day."

Under the heading of "Air Raid Damage" in a publication of the Metropolitan Water Board of London dated August 1941 the following statement was made:

"Since the commencement of the aerial bombardment of the Metropolis approximately 6,000 mains have been damaged including more than 800 of 12 inches diameter and over. The severity of the raids during September and October is reflected in the fact that by the end of the latter month 3,425 mains had been damaged. Of these 403 were trunk and/or feeder mains. Of this total number no fewer than 2,807 had been repaired by the 31st of October, or an average of 370 mains per week. Two heavy raids were experienced in April 1941 when 464 mains were damaged, including 74 trunk and feeder mains. A further raid in May caused damage to 586 mains, of which 74 were of large diameter. . . .

"The lengths of main broken vary greatly but it is no uncommon experience to have four 12 ft. lengths of pipe broken and in certain instances as many as ten 12-ft. pipes have had to be used in one repair."

While we may not expect raids of the intensity experienced in Great Britain, 50 or more breaks with at least 6 or more occuring in mains of 12 in. and over in size during one token raid would not appear to be an unreasonable assumption. Have you made your plans on any such an assumption?

There are a number of things that it seems advisable for the water works officials to consider in preparing for an air raid.

1. Have you properly integrated your activities with the whole defense program?

If not, you will have great difficulty in functioning during an emergency. Remember the Commander, Citizens Defense Corps, has charge of all activities during the emergency.

2. Have you arranged for a representative of your department to be on the staff of the Commander?

The Commander will need his advice as otherwise he may order action that is not compatible with good water works practice.

3. Have you arranged for notification on an alert so that your force may be at their stations before the alarm sounds?

If not, your force may never reach their stations or will arrive so late as to be of little immediate value.

4. Have you arranged for proper identification of your emergency force under the civilian defense program so that they will not be interfered with by air raid wardens and auxiliary police while carrying out their duties?

If not, you may have no emergency force immediately available when and where it is needed. These emergency officials may not recognize the usual forms of identification.

5. Is your water works control or operating center properly tied in with the report or control center set up under the defense program?

In Bristol, England, 95% of the reports to water works were received through the report centers. Usual methods by which reports of breaks in water mains are made may not be functioning.

6. Have you developed your own communication system so that it will function during a raid?

Remember regular telephone service may be curtailed or entirely off.

7. Have you made arrangements for and are you training additional forces?

London was obliged to double its repair and emergency crews. In many cases in this country the normal crews might have to be trebled. Plumbers, both master and journeymen, appear to be a logical group from which to obtain volunteer workers.

8. Have you trained your own office and field force for emergency work?

Office force, meter readers, and the like can be used for gatemen and messengers, if not for the more laborious work. Don't forget this requires planning and training.

9. Have you placed any curb on your employees engaging in other activities in the defense program?

All water works employees should be trained for the emergency work of the department and not as air raid wardens and the like.

10. Are your maps, gate valve locations, and other essential data up to date and ready for use?

You may need this information badly at any time.

11. Have you checked your gate valves? Do you know that they will operate?

No comment is needed on this question.

12. Have you scattered your material and equipment at various locations?

A single bomb may bottle up a central yard.

13. Have you established stations in various parts of the city from which gate crews and minor repair squads will operate?

Gate crews need to be at the incident as quickly as the firemen

in order to operate valves and promptly report the extent of damage.

14. Have you arranged for chlorination squads?

All mains must be chlorinated before being returned to service after repair, and auxiliary supplies that may have to be used must be chlorinated before entering the system. This must not be overlooked.

15. Have you planned with the fire department officials for auxiliary supplies for fire fighting?

This may be essential, as broken mains may limit the amount of water immediately available in any area.

16. Have you made provisions for supplying water to certain sections for domestic purposes during periods when water service is off?

Use of water carts or temporary water lines may be necessary.

17. Have you coöperated with the health department in your planning?

Don't forget that it is responsible for the health of the people.

18. Have you carried on command post exercises?

If not, how do you know your organization will function in an emergency?

19. Have you arranged for increased laboratory examination of water samples from the distribution system as a regular procedure and for a much greater increase following an air raid?

I do not need to stress the reason or the necessity for this.

20. Have you arranged to increase chlorine dosages so that proper residuals can be maintained throughout the system in case an air raid occurs?

London has done this and maintained a better water bacteriologically than was the case before war was declared. This may mean auxiliary or booster stations. Don't forget that the human equation enters the picture and that chlorination of mains before being restored to service may not be perfect.

These are by no means all the questions that I might put to you, but if you can answer "yes" to each of these questions I believe that your part in the civilian defense program will function properly.

In this paper I have not attempted to outline methods for maintaining service since that is something that water works officials are trained and experienced in, nor have I mentioned methods of maintaining the bacterial safety of the water delivered to the consumer.

You all know the methods and would be expected to apply them under all circumstances.

The responsibility for maintaining an adequate and safe water supply at all times, regardless of what may happen, is a great one, since the continuation and well-being of the city depends upon it. I know that this responsibility will be met here as it has been met in Great Britain. But I urge you to be ready and not to be caught short.

DESIGN AND CONSTRUCTION OF PRELOAD TANKS AND DOMES

BY ANDREW C. LINBERG*

[*Read January 15, 1942.*]

When reference is made to concrete tanks, especially around the Northern sections of our country, water works men are too inclined to turn thumbs down, and one really cannot blame them for that. The history of concrete tanks in this section of the country is such that mere reference to the matter calls to mind a picture of the many unsuccessful tanks that decorate the New England landscape, monuments to incorrect application of certain engineering fundamentals. New England tanks already built, with few exceptions, have been complete failures. They have had to be waterproofed with membrane linings, which in turn had to be protected by Gunite, brick or similar products, and, in many cases, the concrete has disintegrated to the point where the owners have been compelled to discontinue further use of the structure.

These failures have been blamed on various agencies such as segregation of and inferior aggregates, water gain, insufficient cement, metal joints, and all the other common ailments attributed to bad concrete. The real difficulty, in our opinion, however, has been overlooked by many. The elongation of circumference in loading, and by this we mean the stretch of the band rods, has been far beyond the capacity of the concrete in which it is encased, thus causing the formation of numerous cracks, sufficiently large to permit the passage of water. During cold weather, this water freezes, with the result that the expansion of the ice destroys the concrete.

We may liken this construction to that of a wood stave tank. If we should build such a tank, and, after the staves have been put in place, we should tighten the rods only sufficiently to bring the staves into contact at their edges, the result would be readily foreseen. The filling of the tank with water would exert hydrostatic pressure, the

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FIG. 1.—A "PRELOAD" TANK 50 FT. IN DIAMETER AND 100 FT. HIGH.

FIG. 2.—THE OPERATION OF LOADING THE WALL BARS. THE TWO LOWER WRENCHES RESIST TWISTING OF THE BARS.

hoops would be expanded in circumference, and the staves would separate and no longer be in contact. The result is obvious.

This should not be the procedure, however. To avoid the difficulties just described the bands should be drawn very tightly around the wood staves, the staves not only thrown into heavy compression, but the bands subjected to tension almost up to their full loading. When such a tank is filled, the rods are stretched a slight additional amount, but the adjustment is such that the staves will remain in compression and in tight contact at the edges.

The hoop rods in a conventionally designed tank could, therefore, be likened to the binding of a wood stave tank, wherein the bands are tightened only sufficiently to bring the staves into contact.

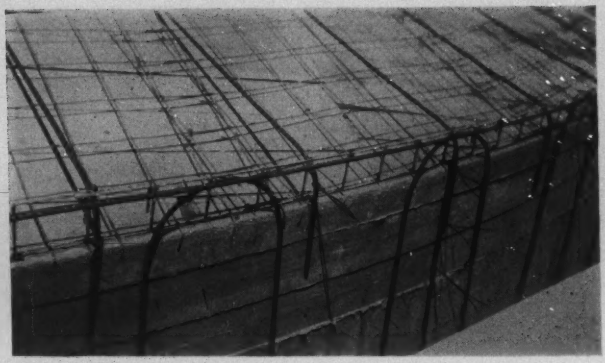

FIG. 3.—ARRANGEMENT OF BARS, STANDARD DEFORMED AS WELL AS PRELOAD, AT TOP OF TANK WALLS. THE TOP (LOOPED) PORTIONS OF VERTICAL PRELOAD RODS ARE BONDED TO THE WALL AND THEN LOADED, OR STRESSED.

The increase in circumference in a wood tank separates the staves, while the increase in circumference of the concrete tank separates the segments of the walls. Is it not, therefore, logical that if the bands are highly stressed, as in a wood stave tank, the concrete would have no tendency to crack? This is the theory on which the Preload System is based. The concrete shell is first erected with only a small amount of reinforcing. This we call the "compression wall". After a sufficient setting period, seldom more than a few days, the hoops and vertical rods are installed, and stressed or tightened a predetermined amount which is readily computed.

We all know that when a load is applied to steel reinforcement, it will stretch or shorten in direct proportion to the amount of the load. Thus, if a load of one thousand pounds is placed on a steel reinforcing rod, it will stretch or compress a certain amount, depending on the area of the cross-section; if the load applied is ten thousand pounds, then the change in length would be ten times as much. Measurements have determined exactly how much this change is per pound of stress, and it is set up in a figure called the modulus of elasticity. The modulus of elasticity for steel averages 30,000,000 lb. per sq. in., and for concrete, about 3,000,000 lb. per sq. in. This figure is ob-

FIG. 4.—PRELOAD BARS ON DOME RING BEING LOADED. NOTE STRAIN GAGE ON TOP BAR.

tained by dividing the unit stress applied, by the unit of deformation, or strain obtained, and is constant up to the "elastic limit" of the material being stressed. By elastic limit is meant that point beyond which a material will take a permanent deformation. This point, in steel, is called the "yield point", and beyond this is the elastic limit which is the amount of applied unit stress beyond which the steel will deform rapidly with very little additional stress. Steel for tank purposes can be considered safe up to the yield point and perfectly elastic up to the elastic limit.

In concrete tanks of convention design, the stress of steel reinforcing rods under applied load is a critical factor. Low working stresses must, therefore, be used to keep this stretch to a minimum. Steel is exceptionally strong in tension, but concrete, for the purpose of design, has been considered to have no tensile strength. When steel and concrete are bonded together during construction, they must act together as a unit. Theoretically, the steel makes the tension and the concrete is to be unstrained in this respect.

But how can this hold true? For each pound of load applied, as the tank is filled, the steel will elongate a definite amount, and the concrete being bonded to it and subject to the same loading, must also elongate by the same amount exactly. Since the modulus of elasticity

of steel is ten times that of concrete, the stress ratio is at 10 to 1, and the unit stress of concrete under load will be one-tenth of that in the steel. If the unit tensile stress for steel is 12,000 lb. per sq. in. under load, then the concrete is required to take a unit load of one-tenth of this amount, or 1,200 lb. per sq. in, which it is unable to do as the tensile strength cannot be more than one-half of this amount; the concrete, therefore, breaks. The hope is that the breaks will be numerous and the openings small.

Under the Preload design, practically all the disadvantages stated are eliminated or controlled. The trouble has been that steel and concrete would not coöperate as they were tied together to work as a unit and this was impossible. The initial stresses were in reverse, and righting them played havoc with the structure. Now we separate steel and concrete, and work each to the limit of its capacity; we begin with the stresses in proper relation, the steel is actually loaded during construction, its friend the concrete serves as a load, and continues in this capacity, except when the tank is filled. The weight of the fluid then takes over the load and frees the concrete, not entirely, but to a stress ranging from 200 to 300 lb. per sq. in. This principle applies not only to tanks but also to beams and other types of reinforced concrete structures where steel is to be stressed in tension.

To put it in a few words, The Preload System is a method of concrete construction whereby the steel reinforcing is preloaded or prestressed against the concrete with which it is combined, in such a way that the live load causes the concrete to release its compression instead of being stressed in tension. Cracking due to loading, shrinkage, or temperature changes, is eliminated.

This system of concrete construction is not new. It was introduced in the United States, as shown in the Patent Office, way back in the eighties. A patent was taken out covering the building of concrete pipes, wherein the steel hoops were stressed by the simple expedient of shrinking them on. The rods were heated and immediately placed upon the concrete. Subsequently cooling induced the stress. The same principle is used in tie rods in almost any bridge of the old type. The first tanks built under a similar method were erected in Northern Minnesota about twenty years ago. These tanks were a great improvement over the tanks of conventional design, and they

are still in service without membrane linings. Refinement and additional improvements have been made through experience gained in the construction of hundreds of tanks since that time. The tanks now being built by our company throughout this country no doubt embody some of the tricks practiced during the construction of the first tanks.

However, there is another source of cracking in concrete tank walls, not caused by the elongation of hoop rods. In the wall there is a considerable difference in temperature between the outside and the inside. During the summer, the outside surface of the wall will reach a relatively high temperature, while the inside remains at the temperature of the water. In the winter time, the temperature of the outside surface may be rather low, while the inside surface will remain at the water temperature. The warmer surface or side will be longer than the cooler side, with the result that vertical tension and unbalanced stresses will be set up in the walls. During the summer, the inside surface may develop horizontal cracks due to this tension. When the temperatures are reversed, due to a change in seasons, the tension is on the opposed, or outside surface, and cracks may occur at the weak sections, which, of course, are opposite the cracking that occurred on the inside face. The result is a through crack, water leakage, discoloration, and eventual failure.

In the Preload System, this condition is overcome by the introduction of vertical preload rods. The wall is placed in vertical compression to an amount that will offset the tension due to temperature changes.

Construction of a dome to cover these tanks is rather an interesting feature of this design, and, incidentally, is adaptable to covering large enclosures where columns are not desired. The dome is supported on a ring abutment which is, in turn, encircled with Preloaded hoops that will take the full thrust of the dome load. Two such domes were built in Brevard, N. C., with a clear span of 155 ft. Incidentally, the thickness of these domes was only 2 in. We consider these domes to be the largest of their kind in the world. Other large domes are: St. Peter's Church dome in Rome, built between 1506 to 1626, a stone dome with a span of 131 ft. and a very high rise, weighing 11,000 tons; the Market Hall in Breslau built in 1913, a reinforced concrete arched rib dome, spanning 213 ft. with a weight of 7,000 tons; and the Market Hall in Leipzig, built in 1929, a reinforced con-

crete shell dome, of the Dywidag type, spanning 246 ft. and weighing 2380 tons. None of these domes are spherical, and they all use arches in one form or another. Now the dome we built in Brevard is perfectly spherical and is not ribbed. Furthermore, its weight is only 340 tons. If we were to build a dome as large as the one over the Market Hall in Leipzig, its weight, including the abutment ring, would be 900 tons or one-third of the weight of Dywidag shell construction. Furthermore, these domes are very strong and capable of carrying heavy weights. We have been furnished proof of this in various instances in connection with some of our tanks. Some have been designed to carry quite heavy loads in the way of machinery concentrated at the crown, and the domes that support this equipment, at least to the layman or engineer unfamiliar with this type of construction, appear to be alarmingly thin. The dome shells on the two 155-ft. diameter tanks previously referred to are only 2 in. thick. However, as little is known in regards to stresses set up as a result of concentrated loads on domes, it was decided a few months ago to retain Professor Walter C. Voss of the Massachusetts Institute of Technology to build a model dome and carry out extensive tests. These tests are now completed and by the middle of 1942, we expect to have in our possession formulae that will permit of greater refinement in the design of domes than is possible under formulae now used.

THE 1941 DROUGHT AND ITS EFFECT ON WATER SUPPLIES IN NEW ENGLAND—A SYMPOSIUM

New Hampshire

[*Read December 18, 1941.*]

Leonard W. Trager.* According to the information published by Mr. A. D. Ross, Meteorologist and Official in Charge, U. S. Weather Bureau at Concord, N. H., a study of precipitation statistics for New Hampshire shows that the 9 months period from January to September, 1941, inclusive, is the driest on record, for the same period of months in 89 years. At Concord, which is the only station in New Hampshire where a detailed and complete long record is available, the January to September total precipitation was 17.3 in., while the previous record low for the same months was 19.1 in. in 1930. The normal total for these months is 28.4 in.

Relative to water supplies and the effect of drought upon them, Mr. Charles D. Howard, Director Division of Chemistry and Sanitation, New Hampshire State Board of Health, in his article, "Water Supplies and the Drought" as published in the *New Hampshire Health News* said, in part, as follows:

"Most of our municipalities have been fortunate in that the extreme drought of the past few months has resulted in acute public water supply depletion in but a very few instances, although in a number of cases reservoirs have been lowered such as to call for special conservation measures. No public supply has failed to the point where consumers have been denied a reasonable use of water. In all cases, any auxiliary supplies of municipal character that may have been resorted to are safe or have been made safe by chlorination.

However, a number of places have instituted or now have in project emergency well construction programs. The town of Farmington has been compelled to supplement its ground water system by drawing from the Cocheco River, with provision of chlorination, this stream being exposed to no appreciable pollutive influences at this point.

*Associate Sanitary Engineer, New Hampshire State Board of Health, Concord, N. H.

The most acute situation has been at Claremont, where the brook reservoir supply became alarmingly low. Here consideration was given to alleviating this in small part by piping in another small brook, but because of certain legal aspects involved it was not deemed expedient to advance this project. While this town has for many years had a number of wells located on an area known as Kelsey's Island, this water has for long been unusable because of an excessive iron content, it being virtually impossible to utilize this source without deferrization treatment. To introduce such iron-impregnated water into the system and into the reservoir would, we believe, be unfortunate, because of the conditions that would tend to be set up.

A rather extraordinary situation in the case of this town is in the fact that a short time ago the water commission proceeded to have constructed near Claremont Junction two large wells which are capable of affording an abundance of water of excellent quality but which have never been piped into the system or accepted by the town because of a legal controversy, certain of the citizens having felt it would be preferable to develop such an emergency supply by gravity flow through resort to a pond in the town of Cornish. However, this pond source subsequently proved to be non-available, and it has appeared that only through action at a special town meeting could resort be legally made to the wells in question. Objections raised to the latter in connection with the town's refusal of acceptance have been that this water is somewhat harder than a pond source would be, and that a rather substantial pumping expense would be entailed. However, utilization of this source would be necessary only in emergency, and in any case such pumping could scarcely be more expensive than the construction and operation of a filtration plant and, it is believed, would otherwise be preferable thereto. Another objection in some quarters, involving apprehension of a hazard of back draft from the river, is not considered by engineers as a valid one, this being a true ground water."

Other public water supply systems that were seriously effected by the drought are Rochester, Troy, Warner, and Bennington, N. H.

At Rochester, it was deemed advisable to conduct studies and surveys for an auxiliary well supply. Test wells were driven, samples taken and analyzed, and the location for the auxiliary well system selected. At Troy, the reservoir was practically empty for a short

period of time in September. Preliminary plans for enlargement of this system were prepared a few years ago, and it is presumed that they will now be reconsidered. At Warner, the reservoir was approaching a critical point until replenished by rains in October, 1941. At Bennington, both the gravity spring system and the Jacques Brook system were seriously affected. Plans were made to pipe water into the system from an old brook source.

VERMONT

EDWARD L. TRACY.* The shortage of water in springs and streams feeding domestic supply systems was more evident during November and December 1941 than during the actual drought period of the summer. Although the deficiency in rainfall was primarily the reason for the shortage, other discrepancies showed up. Several of these could be classed under the heading of inadequacy of the supply system. In some cases, small watershed areas were feeding storage reservoirs; with the stream flow smaller than the water consumption, the reservoirs were drawn down too low, proving that storage was inadequate.

Although some parts of the state, particularly the northeast section, had the least difficulty, the places that were short are widely scattered. Two cities, Vergennes and St. Albans on the west side of the state, drew down their storage until it was obvious that an auxiliary source of supply would have to be used. No public water supply system was actually in a dangerous condition. For this reason it was impossible during the summer to impress on a number of communities the need for an auxiliary, or an emergency, source of water supply.

In January, 1941, the Department of Public Health contacted the villages in the defense industry and cantonment areas. Besides urging precautions against sabotage, we urged proper chlorination and the planning of an emergency source of water supply. This did not receive sufficiently serious attention at the time.

In June the reservoir supplying Springfield, the principal defense industry village, was being rapidly drawn off. The village officials then hurriedly started the installation of a multiple well system. By the time that they were pumping water from the well system, the

*Director, Division of Sanitary Engineering, Vermont Department of Public Health, Burlington, Vt.

reservoir was drawn down very low. The machine shops and additional residences used so much additional water that it was impossible to bring back the water level in the reservoir. This is an example of a storage reservoir with a small watershed area. The same is true of Vergennes and St. Albans.

The meteorological data for Burlington show some interesting facts. The precipitation deficit started in February. By April there was an accumulated deficit of 2.36 in. from normal. On December 1, the 1941 accumulated deficit was 8.18 in. The total precipitation from January 1 to December 1 was 22 in. The normal, or mean, since 1884 for the same eleven months is 30.22 in. Thus the precipitation was 72% of normal during 1941. I believe the 1941 rainfall in New England, as a whole, has been about 75% of normal.

As a matter of comparison, the lowest annual rainfall recorded in Burlington was in 1914 when 22.62 in. fell. The high year was 1897 with 43.44 in. In 1914, the low year, the precipitation for the eleven months to December 1 was 21.37 in. The year 1941, therefore, was very little above that. This illustrates the seriousness of the condition.

The value of reforestation was well demonstrated. Rutland has forty-five hundred acres of city owned land on a watershed of about twenty-four square miles. On this city-owned land adjacent to water supply streams, about one and one-third million trees have been set out since 1916. The cutting of existing timber has also been well controlled. The city has a population of 17,500. The reservoir holds only five million gallons. The average per capita consumption of water is over two hundred gallons per day and yet, during 1941, there was no actual shortage of water in that city.

Lake Champlain, from which Burlington and Alburgh take their domestic water, was about three feet below normal in the late summer. This has come back about one and one-half feet. The water systems drawing from the lake were not affected.

The principal villages, except those already mentioned, have had sufficient water, although some of their reservoirs were below normal. They include Brattleboro, Bellows Falls, Bennington, St. Johnsbury, Montpelier, Barre, and Newport. The White River Junction system did not supply sufficient water but their distribution system is connected to West Lebanon, N. H., which furnished part of the water beginning in August.

The water shortage of 1941 will result in the improvement and enlargement of some of the affected supply systems. It may promote metering, which is not usual in Vermont except in Burlington. For instance, Windsor, a national defense village, is using all of the water available at the present source of supply. Additional sources are not readily available. It may be necessary to meter this village to conserve water, so that there will be a sufficient quantity for the industrial plants.

The development of auxiliary or emergency sources of supply will, I believe, lead to more chlorination in the state. The Department of Public Health will not approve the use of water from open streams unless it is chlorinated.

Massachusetts

Ralph M. Soule.* During 1941, Massachusetts experienced the worst drought in over 50 years. After September, 1938, the month of the great hurricane flood, the accumulative precipitation fell below normal throughout the state, so that at the end of November 1941, a period of 38 months, the accumulative deficiency was 18.3 in. below normal. Many water works men have looked upon the period of 1908 to 1911 as the driest on record, but the records of the Massachusetts Department of Public Health show that during the period from October 1908 to November 1911, inclusive, the accumulative deficiency was only 17.6 in. From October 1928 through November 1931, another dry period, the accumulative deficiency in precipitation was 16.8 in. Of these three very great dry periods then, the present drought exceeds that of 1908 to 1911 by three quarters of an in. and that of 1928 to 1931 by an inch and a half.

During the drought of 1941, the twelve-month period from December 1, 1940 to November 30, 1941 was the most critical with a deficiency of 11.0 in., or a total precipitation more than 25 per cent less than the normal. This also exceeds any similar twelve-month period in the past. During this period, every month, except June and July 1941, was below normal in precipitation, the greatest departure from the normal occurring in September, when an average of 0.96 in. of rain was received over Massachusetts.

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On the basis of the climatological year which begins on October 1 and ends on September 30 in the following year, the climatological year 1938 to 1939 was 6.2 in. below normal. The year 1939-1940 was almost normal, adding only 2.3 in. to the accumulative deficiency. The year 1940-1941, however, added 7.7 in. and the first two months of the climatological year 1941-1942 added 2.1 in. so that at the end of November 1941 the total accumulative deficiency was 18.3 in., and such preliminary results as are available for December indicate that this deficiency was not materially decreased in spite of the heavy precipitation of December 13. (See Fig. 1.)

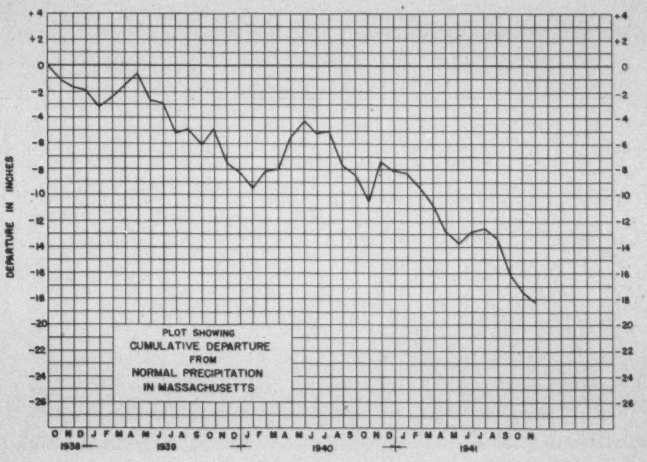

FIG. 1

There has been considerable variation in the deficiency in rainfall in various sections of the State. The Northeastern section has been the hardest hit by the drought, having a total accumulative deficiency in precipitation of 27.4 in. The Southeastern section, which includes southeastern Massachusetts and Cape Cod, has fared the best, having an accumulative deficiency of 11.3 in. The accumulative precipitation since October 1938 in the Southeastern section was above normal from March to June, 1939, inclusive, and in May,

1940. The month of September, 1941, however, was drier in the Southeastern section than anywhere else in the State; an average of 0.16 in. was received, and the greater part of this on the last day of the month. (See Fig. 2.)

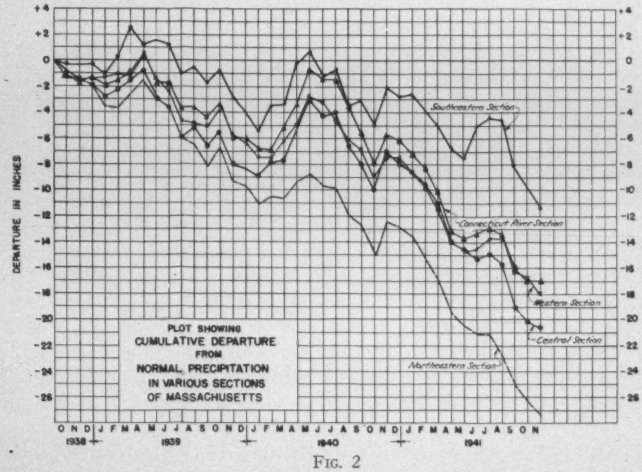

FIG. 2

The Connecticut River section had an accumulative precipitation deficiency from October 1, 1938 to November 30, 1941 of 16.9 in., the Central section a deficiency of 24.9 in., and the Western section a deficiency of 18.0 in. After May 1941 the deficiency in the Central section increased more rapidly.

The deficiency from October 1, 1940, to November 30, 1941, was greatest in the vicinity of Wilmington and Concord in the Northeastern section of the State; it received only about 68 per cent of the normal precipitation. A comparatively large area in the Central and Northeastern sections, extending from Hubbardston to Beverly, was more than 14 in. deficient and received only about 72 per cent of the normal rainfall. Two other smaller areas, one in the vicinity of Springfield and Chicopee and another in the vicinity of Montague and Greenfield, were also deficient by more than 14 in. A short dis-

stance west of these areas, in the foothills of the Berkshires, the deficiency was only 6 in., and the precipitation received was 88 per cent of the normal. (See Fig. 3.)

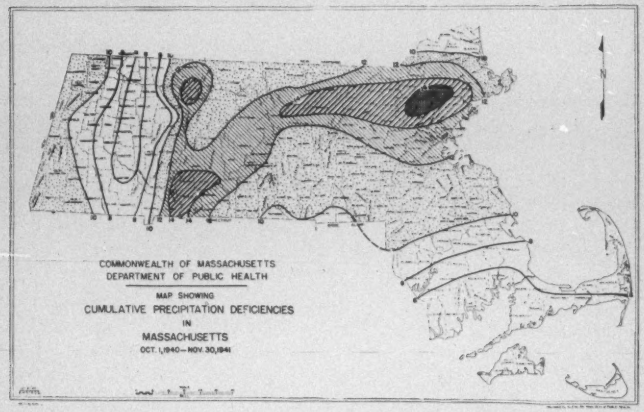

FIG. 3

Cape Cod, which had a somewhat higher normal rainfall, was only 6 in. deficient and received 89 per cent of the normal precipitation. In the extreme Northeastern section, in the vicinity of Haverhill and Newburyport, the deficiency was 10 in., but the normal precipitation is lower in this locality than in other parts of the State and the percentage of precipitation received after October 1, 1940, was only about 80 per cent of the normal.

In the Northeastern section of the State, where the precipitation deficiency was greatest, there are nine municipalities whose water supplies were at a very low point. In the Central section, where the precipitation deficiency was next highest, there are six water supplies that were also at a very low point. In the Connecticut River section, three municipalities were experiencing a water shortage, and in the Western section only one. In the Southeastern section no cities or towns were reported to the Department of Public Health as having a shortage of water supply.

While the large deficiency in rainfall was the primary factor in the water supply shortages, conditions were made worse by increases in water consumption due to National Defense activities. The following is a summary of conditions in the municipalities where water shortages were being experienced:

Dracut. While no shortage of water supply existed in the Dracut Water Supply District, it was necessary for the district to use the Lakeview supply which contains a considerable amount of iron. Work was undertaken on the installation and testing of a new gravel-packed well.

Ipswich. During the early fall, a water supply shortage was experienced in the town of Ipswich, but this was relieved by a material drop in the water consumption, and an additional supply was made available from a new gravel-packed well.

Lowell. The condition of the water supply of the city of Lowell was investigated by a consulting engineer employed by the mayor. Should the drought continue, it will be necessary to install additional wells.

Marblehead. The water supply of the town of Marblehead was seriously diminished by the drought and the town continued to buy water from the city of Lynn. Lynn may also be called upon to supply water to adjoining municipalities since, in general, the region embraced by the cities of Salem, Beverly, Peabody and the towns of Danvers, Saugus, Middleton and Marblehead, lies within the areas where the greatest deficiency in rainfall existed.

Newburyport. The lower reservoir of the city of Newburyport was drawn down for cleaning in 1938 and not refilled. This factor contributed to the water shortage, causing the upper reservoir to drop to a very low level. Consideration was given to obtaining small amounts of water from adjoining communities, but because of the excessive costs this plan was abandoned. Test wells were driven by the city with a view to obtaining a tubular well supply in the city at some point where water may be pumped directly into the distribution system.

Peabody. The supply of the city of Peabody reached a very low point. The city was unable to pump water from Ipswich River because of legal limitations protecting the low-water flow of the stream. A conference was held early in December with representa-

tives of the adjoining cities, the town of Danvers, and the Department of Public Health with a view to coöperative action in meeting the deficiency of water supply in the city of Peabody. The town of Danvers was prepared to supply as much as 500,000 g.p.d. to the city of Peabody. The city of Lynn was prepared to supply 200,000 g.p.d. and possibly more if an adequate number of inter-connections between the distribution system of the city of Peabody and the city of Lynn could be made. Lynn, however, also depends upon pumping from the Ipswich River for a large part of the yield of its water supply and was also unable to pump from this river during the low stream flow conditions. The city of Peabody investigated the possibility of an auxiliary water supply in the valley of Humphrey's Brook which leads from Suntaug Lake to the Ipswich River.

Wenham Lake, the source of water supply for the cities of Salem and Beverly, was on December 1, 1941, 14.7 ft. below full reservoir. This is the lowest elevation ever recorded since Wenham Lake has been used as a source of water supply. The amount of available storage on December 1, 1941, was 975 m.g., or about 150 days' supply. Officials of the Salem and Beverly Water Supply Board proceeded with the installation of emergency pumps to lift the water of Wenham Lake within reach of the low-lift pumps of the treatment plant.

Other towns in the Northeastern section that experienced a shortage of water supply in the fall of 1941, but that have since been relieved because of a material drop in the water consumption, were Amesbury, Concord, Hamilton and Lincoln.

Fitchburg. Officials of the city of Fitchburg were of the opinion that if the drought continued, the water supply would be in a serious condition by the first of February, 1942. The condition of the supply was particularly serious on the high-service system. Consideration was given to the installation of emergency pumping equipment in Meeting House Pond and Wachusett Lake if the elevation of these reservoirs should drop below the intakes.

Leicester. The Leicester Water Supply District received water from the Cherry Valley and Rochdale Water District in order to meet their shortage.

Milford. The Milford Water Company, which serves the towns of Milford and Hopedale, experienced a shortage of water in its stor-

age reservoir, and tubular test wells were driven with a view to establishing an auxiliary well supply.

Millbury. The Massachusetts Water Supply Company in this town was required to refuse service to a large industrial establishment in order to maintain an adequate water supply for other consumers.

Spencer. The elevation of Shaw Pond, the usual water supply for the town of Spencer, dropped in elevation so that there were less than 2 ft. of water over the intake. Approval was given the town by the Department of Public Health to use the water of Whittemore Pond as an auxiliary source as soon as the microscopical organisms were reduced to a number that would not result in disagreeable tastes and odors. Water taken from this pond must be adequately chlorinated at all times.

Worcester. The reservoirs of the city of Worcester, were depleted in October to a point so that there was only about 30 per cent of the total storage remaining. Water was pumped from Quinapoxet Pond when available and from Wachusett Reservoir. The situation on the high-service reservoirs was relieved by pumping water from the low-service reservoirs into the high service. The water consumption of the city averages about 20 m.g.d. or nearly twice the amount being pumped from Wachusett Reservoir.

Other supplies in the Central section of the State, that experienced shortages of water supply but were relieved because of a material drop in the water consumption, or the development of auxiliary sources, were Ayer, Brookfield, Clinton, Leominster, Marlboro, Northbridge and Paxton.

Shelburne Falls. The Shelburne Falls Fire District recently installed a group of tubular wells as an emergency source of water supply in order to relieve a serious water shortage experienced in the month of September.

Pittsfield. The city of Pittsfield was relieved in October in its water shortage by the use of Onota Lake.

Metropolitan District. In connection with the Metropolitan water supply, Wachusett Reservoir steadily decreased in elevation from the latter part of April to September 17, 1941, at which time it was at elevation of 366.0 or 29.0 ft. below the spillway. On this date, Metropolitan Water Works officials began discharging water from Quabbin Reservoir to Wachusett Reservoir at the rate of about 475

m.g.d. This was continued until October 28, and during that period Wachusett Reservoir gained 12.4 ft. in elevation in spite of the fact that about 187 m.g.d. were being drawn from the reservoir.

From October 28 to December 12, 1941, Wachusett Reservoir lost 5.4 ft. in elevation, and, on December 12, it was 23.0 ft. below the spillway. There are, however, about 120 billion gallons of available storage in Wachusett and Quabbin Reservoirs or about 800 days' supply for the Metropolitan Water District. There was a deficiency from the normal yield of the Wachusett Reservoir drainage area for every month from August, 1940, to October, 1941, inclusive. The rainfall received on this watershed during this period was 39.8 in., which is 17.3 in. below the normal. The rainfall collected was 26.1 in. which is 11.7 in. less than the normal.

The deficiency in rainfall also resulted in unprecedentedly low flows of streams. During the early part of October, 1941, the flow of the Charles River at Waltham averaged only about 4 m.g.d., as determined from records of the U. S. Geological Survey. Because of the small amount of water entering the basin from the Charles River, it was necessary to introduce larger amounts of salt water through the locks at the dam, with the result that the salinity of the water in the basin was considerably greater than that under normal conditions. As a result, a large number of fish migrated to the upper end of the basin in the vicinity of Watertown where, because of the shallowness of the water, the increased temperature, the small amount of fresh water entering the basin, and the low oxygen content of the water, many fish were unable to survive and it was necessary for the Metropolitan District Commission to remove dead fish weighing in excess of several tons at Watertown.

Between October 9 and November 4, 1941, the Metropolitan District Commission, in flushing out the Cochituate Aqueduct, discharged about 25 m.g.d. into the Charles River, and this materially improved conditions.

RHODE ISLAND

WALTER J. SHEA.* It may be said that the effects of the prolonged period of subnormal precipitation on Rhode Island water sup-

*Acting Chief, Division of Sanitary Engineering, R. I. Department of Health, Providence, R. I.

plies did not cause widespread hardship up to December, 1941. Those suffering the most were residents of rural areas who depend upon shallow wells or springs as sources of drinking water supply. Many of these sources dried up. It is estimated that about 7 per cent of the population of the state, approximately fifty thousand people, obtain water from private sources, and since many of these use deep wells, or shallow wells that continue to yield water due to their good location, it is improbable that more than a few thousand people were left without their usual source of water supply. Nevertheless, some of these people who must provide water for cattle as well as household uses, which is obtainable only at long distances from the usual source, were getting along under great difficulties. A considerable number of applications for connections to public water supply systems, from property owners previously served by wells that are now dry, were reported by water works superintendents.

The shortage of water experienced by one of the smaller public water supplies made it necessary for high-service areas on the system to get along with but a trickle of water from taps, and resulted in pressures throughout most of the system, too low for satisfactory fire protection. This situation was remedied in a short time by the development of wells to augment the lake supply formerly used.

Operation, for brief periods, of two small supplies under pressures too low for fire protection and high service was caused by loss of water through breaks in mains occurring when low water levels in wells made it impossible to restore the lost water to the systems in a reasonable period of time. In one of these cases, it was necessary to heavily chlorinate water from an emergency source and pump it into the distribution system to fill the standpipes and restore fire protection. In the second case, a connection with another system replenished the lost supply of water.

The water level of Wallum Lake which supplies the State Sanitorium fell 8 ft., leaving only 16 in. of water over the end of the intake pipe. The end of this intake, under normal water level conditions in the lake, is located 70 ft. off the shore line, but was only 7 ft. off the contracted shore line. Since it is not unusual to cut 30 in. of ice on this lake, it was feared that the end of the intake might become icebound. It was proposed to connect an abandoned intake which extends to a deeper part of the lake to the present suction line to meet

this contingency. It seems worth mentioning that the increased suction lift created by the low level of the lake made it necessary to extend the daily period of pump operation by fifty per cent.

The larger water supply systems of the State were affected by the drought, to a greater or less extent, depending of course upon size of watershed, storage capacity, and demands on the system.

The Providence system supplies nearly one half of the population of the State. Because of a large watershed and a storage capacity of 37 billion gallons, when the reservoir is full, it is estimated that a minimum of 85 m.g.d. can be supplied safely during the driest years that may be expected, whereas consumption was only a small fraction of that rate. The level of water in the reservoir dropped to 13.7 ft. below the spillway, compared to 11.6 ft. in October, 1940, and 19.2 ft. in December 1930. The town of East Providence has an impounding reservoir of 420 m.g. capacity located at the lower extremity of a large stream, The Ten Mile River, and as water has flowed over the spillway continuously there is little prospect of the town lacking water.

The cities of Pawtucket and Woonsocket are less fortunately situated than Providence and East Providence as regards the size of the drainage areas from which they can collect water. Their reservoirs were less than half full. While there was no immediate cause for alarm, these supplies are not in a favorable position to withstand an extended prolongation of the dry period.

It is unfortunate that the greatest demands for water coming from military areas were placed upon insular water supply systems, namely, the Newport and Jamestown systems. Because of the very limited drainage areas on the islands available to these communities, greatly increased demands and drought conditions would require obtaining water from the mainland at great expense. Appeals to consumers to conserve water were made by the superintendents of these supplies. A federal grant of money was made to the city of Newport, under the Lanham Act, for the construction of a dam, reservoir, and treatment plant to develop 1.1 sq. miles of watershed now undeveloped. A contract for construction of this project was expected to be made without delay.

It is of interest that the situation in Newport would have been acute, if the superintendent of the supply had not begun to let water

down from an upper reservoir to a lower one and continued to do so over this period of the drought. Because of the flat grade between the two reservoirs, and the small capacity of the brook that is used to carry water from the upper to the lower one, the transfer must be effected over a long period. It is estimated that the reservoirs contained about a ten weeks' supply of water. It is a coincidence that drought conditions accompanied excessive military demands on the Newport supply also during the last world war.

The Jamestown supply was in a similar position to that of Newport but on a reduced scale. Steps were under consideration to increase the storage capacity of this supply.

No attempt has been made in this brief survey of water supply conditions in Rhode Island to cover all the water supplies of the State. Only representative ones and some that faced special problems have been mentioned. It should be borne in mind that accompanying the prolonged period of subnormal precipitation there have been placed upon our water supply systems greatly increased demands for water from military areas, new housing projects, and increased industrial use of water. There are instances in which private sources of water for industrial uses dried up and industry was forced to turn to municipal water supply systems for large volumes of water not needed normally.

Connecticut

Warren J. Scott.* Connecticut experienced a period of severe drought beginning in July, 1940, when the rainfall began to drop below normal. In Hartford, the rainfall from the beginning of July, 1940, was below normal in every month except November, 1940, and June and July, 1941. September and October, 1941, produced nearly a record two-month drought.

There was some difference in the severity of the drought over the State. The Hartford and New Haven figures may be cited as indications. The Hartford records go back to 1868, and a review of the rainfall since 1868 shows that the four-month, 1941 rainfall of 9.0 in. from August through November was less than in all but the years 1931 and 1914. In New Haven, however, not far distant, the rainfall

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in this same four-month period in 1941 was 10.7 in., 1.7 in. in excess of Hartford. New Haven rainfall records go back continuously to 1873, and intermittently, with some long interruptions, to 1804. Going back as far as 1873, the four-month, 1941 rainfall in New Haven (August through November) exceeded the rainfall in the corresponding period in eight years: 1935, 1922, 1917, 1916, 1914, 1912, 1900 and 1899. The cumulative rainfall deficiency below normal in Hartford from July 1, 1940, up to December 1, 1941, was 15.5 in. whereas in this same 17-month period in New Haven, this cumulative rainfall deficiency was only 12.4 in.

Connecticut experienced severe drought conditions in 1922, 1923 and 1924 which produced depletion of some public water supplies and threatened the exhaustion of several more. Notable among the seriously depleted systems where auxiliary supplies had to be pressed into service were those of Derby, Shelton, Norwich and Farmington. Since then, numerous important water supply enlargements were carried to completion. Among these might be listed the construction of the Deep River Reservoir in Norwich, the North Branford Reservoir in New Haven, the Barkhamsted Reservoir in the Hartford Metropolitan District, the Saugatuck Reservoir in Bridgeport, the Shepaug diversion in Waterbury, the Margerie Reservoir in Danbury, the Reuben Hart Reservoir in Torrington and the Laurel Reservoir in Stamford. Connections were made between the Bridgeport system and the water systems of Shelton and Derby, between the Hartford system and the systems in Unionville, Farmington and East Hartford, between the Stamford system and the Greenwich system, and between the New Britain system and the Plainville system. Recently the Plainville system has been connected with Bristol whose storage was enlarged several years ago. Auxiliary well supplies have been constructed in Terryville and Jewett City. A temporary connection was made between the Middletown and Portland systems during one drought period but has since been broken. While this list is by no means complete, it does indicate the extent of the measures that have certainly helped to counteract the effect of the drought of 1941 upon our public water supplies.

It hardly needs to be stated before a group of water works men that planning for water supply is of far more importance than in many fields of activity. The long road of drawing up engineering

plans, securing local approval of municipalities or boards of directors, obtaining legislative authorization, going through the processes of land acquisition and possible land condemnation, and finally building reservoirs, pipe lines, tunnels, pumping stations, treatment plants, or numerous other types of structures, is well known. Sometimes, in the case of large projects, ten to fifteen years or more have been consumed in traveling to the end of the road.

Connecticut can point with pride to the sufficiency of the vast majority of its water supplies to cope with droughts. The 1941 test was all the more severe because of the tremendous increase in water consumption due to defense activities. Connecticut has been a beehive of activity, and scarcely a city or large town has not felt the defense impact. Industrial plants of major importance to the Nation's defense are scattered from one end of the State to the other. Guns, planes, boats, machines, metals and numerous other necessities have been produced. The increase in water consumption in 1941 has to be borne in mind in comparisons between conditions during this recent drought and those during droughts in 1931 or the early 1920's.

No public water supply in Connecticut failed in 1941, although some interconnections were placed in service. Public water supplies were dangerously depleted in Middletown and Wallingford. In the former city, plans were laid to pump from emergency sources if necessary and the latter community began plans for a new reservoir. Storage on some supplies was seriously lowered.

Two points in connection with droughts such as that of 1941 appear worthy of comment. First, new cumulative lows in rainfall and stream flow may be taking place in certain areas. It would greatly help in water supply planning if more water works men kept records of their stream flows, gains and losses of reservoir storage, and water consumption, which may be tied in to compute dry weather yields from watersheds. Secondly, the adverse effect of droughts should be impressed upon the consumers and those in control of water supply operations. More serious droughts may occur in the future. Now is the time for the water works superintendent in a community affected by the drought to sell the idea of having an engineering study of his system made and laying plans for the future. There is no more serious threat to the well-being of the community than depletion of the public water supply.

PROCEEDINGS

March, 1942, Meeting

Hotel Statler, Boston, Mass.

Thursday, March 19, 1942

President Francis H. Kingsbury in the chair.

Secretary Gifford announced the election of the following:

Members: Malcolm P. Brown, Superintendent, Water Department, Hamilton, Mass., J. Allen Goguen, Water and Sewerage Work, Gardner, Mass., Thomas D. Walsh, Superintendent, Public Works, Winsted, Conn., and Leon H. Reed, Commissioner of Public Works, Pittsfield, Mass.

Associate: The Greene Rubber Company, Brookline, Mass.

Mr. Gifford read the following letter, received by him under date of March 4, in reference to tires for water works purposes.

"This will acknowledge your letter of February 20 with enclosed resolution regarding tires.

The problem of tires for passenger cars used by inspectors, maintenance men, engineers and technicians in enterprises such as your own, is one for which we are as yet unable to provide an entirely satisfactory solution. We are fully conscious of the necessity of these services but simply do not have enough rubber available.

In order to provide tires for the hauling of the most absolutely essential materials and supplies, and for the mass transportation of the workers, it has been necessary to completely suspend all production of automobile tires and the stock on hand is being reserved for such vital services as doctors, fire and police protection, and mail delivery.

Under these conditions there is only one possible course, and that is to make present tires last as long as possible. Accordingly, we have placed retreading and recapping under rationing control and have designated that passenger cars used in the most essential business services shall be included among those eligible. The general public will be unable to obtain retreading or recapping services.

In view of this we suggest that your members contact their local Tire Rationing Boards to determine to what degree they may now be eligible for retreading and recapping, and to make application for such service for any eligible cars. We cannot guarantee that there will be enough rubber to retread the tires of all eligible applicants, but we do feel that there will be enough to provide some measure of relief in the matter regarding which you wrote us."

Mr. Gifford then read the following communication from the Department of the Interior, Office of Solid Fuel Coördination.

"The dislocations of normal business which attend war will affect the fuel supply in many ways. The seriousness of this situation prompts me to solicit your coöperation in communicating with coal consumers with whom you are in contact in an effort to get them to take appropriate steps to protect themselves and make it less likely that fuel shortages will occur.

The war not only is increasing the need of the coal, but it will materially affect the ability of the coal mining and transportation industries to meet requirements. As the war production program gathers momentum, its effect upon these industries will become more and more pronounced. Shortages of steel, rubber, electrical equipment, and other materials which they must have to maintain operations already are being felt, and will become more acute. The burdens of transportation will grow, and the interruptions of ordinary business activities will become more frequent.

Although there is no shortage of coal now, there is serious reason to believe that after the war production program gets fully under way there may be times when consumers will find it difficult to get the particular kind, qualities and sizes of coal which they customarily use. There may even be instances where, due to temporary local shortages, consumers may not be able to get coal of any kind at the time they want it.

The President has requested Secretary of the Interior Harold L. Ickes to carry on such programs as will assure that an adequate supply of solid fuels will be available, where and when needed in this National Emergency. The Office of Solid Fuel Coördination has been established to aid in this undertaking. A study of the information available to this office convinces me that wise consumers will take immediate steps to use surplus mine and transportation capacity while it is available to store reserve coal supplies as protection against possible shortages. And, as they use up their coal, consumers should seize every opportunity to keep their fuel bins replenished.

By using production and transportation capacity to acquire coal for storage whenever they find it available instead of waiting until their coal bins are empty, consumers also will help the mines and the railroads and other carriers to maintain steadier operations and obtain fuller use of their equipment. This will aid in reducing the burden during periods of peak demands when difficulties are more likely to happen, and make less likely that the shortages will occur.

Furthermore, I should like to impress upon consumers the necessity for prompt unloading of coal-carrying equipment at destinations, to enable its quick return to loading points for reloading, in order that maximum efficiency can be obtained from transportation facilities. Purchasers who receive coal in carload lots must not use railroad cars for storage purposes under any circumstances. As Acting Director of Solid Fuel Coördination, I respectfully request the coöperation of your organization in conveying this message to such of your members who are coal users.

Sincerely yours,

(Signed) H. A. GRAY.
Acting Director."

The President announced the death of Mr. Edward M. Shedd of Malden.

Howard C. Mandell presented the following resolution:

WHEREAS the water supply systems of the United States serving vital defense industries and communities constitute the most important single source of raw material and the most important single public utility; and

WHEREAS the damage or destruction through sabotage or war action of water systems serving vital defense industries and communities would greatly imperil the national war efforts; and

WHEREAS proper and adequate guarding of these water utilities is a problem of serious importance to the operators of such utilities,

BE IT THEREFORE RESOLVED that the New England Water Works Association request the War Department to appoint a duly qualified officer or officers to study this problem in coöperation with a representative or representatives of the leading water works associations of the country to the end that satisfactory solution of the problem be arrived at promptly.

A paper, "Barre, Mass., Water Supplies—Old and New," was read by Howard E. Bailey, Consulting Engineer, Boston.

A paper, "Hill, N. H.—A Planned Town," describing how construction of flood control reservoir resulted in establishment of an old community at a new location, illustrated by colored lantern slides, was read by John L. Hayden of Hayden, Harding, and Buchanan, Consulting Engineers, Boston.

Motion pictures showing "Activities and Operation of the Boston Fire Department," and including pictures of the destruction of the Hindenburg, and also pictures of the London Fire of 1940 caused by incendiary bombing, were shown by James Donovan, Aide to Fire Commissioner Reilly.

APRIL, 1942, MEETING

Joint Meeting of the
New England Water Works Association
and
New England Health Institute

HOTEL BILTMORE, PROVIDENCE, R. I.

Thursday, April 23, 1942

President Francis H. Kingsbury in the chair.

President Kingsbury submitted the following report on the guarding of public water supplies:

At the meeting of the New England Water Works Association on March 19, 1942, a resolution was passed which asked that the New England Water Works Association request the War Department to appoint a duly qualified officer or officers to study the problem of proper and adequate guarding of water utilities in coöperation with a representative or representatives of the leading water works

associations of the country to the end that a satisfactory solution of the problem be arrived at promptly.

In accordance with this resolution your President communicated the contents thereof to the War Department. Under date of April 3, 1942, your President received the following communication from John P. Smith, Major General, Chief of the Administrative Services, Headquarters, Services of Supply, War Department, Washington, D. C.:

"Your letter of March 24, 1942, with inclosed resolution, addressed to the Secretary of War has been referred to this office for consideration and reply.

The matter of adequately protecting water supply systems has been studied in detail by the National Technological Civil Protection Committee and the Association of American Water Works. The report of the first group is on file at the headquarters of the Commanding General, First Corps Area, Boston, Massachusetts and copies of the American Water Works study are inclosed herewith. Additionally the United States Public Health Service and the Office of Civilian Defense have information on this subject.

Should you desire further advice from military authorities it is suggested you contact the Commanding General, First Corps Area."

The report of the American Water Works Association therein referred to was a brief of the action of the Board of Directors of the American Water Works Association at its annual meeting on January 19 and 20, 1942, which has been given wide publicity in engineering periodicals. The essence of that report, so far as it relates to guarding, is contained in Paragraph 8, which is quoted in part, as follows:

"8. Consideration of the need for special guards about water works property resulted in adoption of the following statement by the American Water Works Association's Board of Directors in a meeting held on January 20, 1942:

WHEREAS, Experience abroad has not indicated the necessity for maintaining an elaborate and costly guard of all water works plants, and

WHEREAS, A careful survey may be necessary to insure the most effective measures of protection within reasonable limits of costs, and

WHEREAS, Guarding of vulnerable points may be effected by permanent guards or roving patrol the efficiency or economy of which only such a survey will show,

Now therefore be it RESOLVED, That it is the recommendation of this Board that each person or body responsible for the operation of a water supply system cause to be made a confidential survey of water works structures under their supervision to ascertain the points of vulnerability so that protective measures both in equipment and personnel can be effected to the extent necessitated by local requirements."

It will be noted that in the second preface to the resolution a careful survey may be made necessary to insure the most effective measures of protection within reasonable limits of cost. It is your President's understanding that such surveys have been made in most of the New England States by water works officials assisted in some instances by the State military authority and in others with the assistance of the Departments of Public Health and State Police and that the guarding of municipal water supplies vital to war production has been scrutinized and recommendations made for improving such guarding.

The other report referred to in the letter from Major General Smith is that made by the National Technological Civil Protection Committee entitled "Engineering Aspects of Protection of Civilians and Their Work Against Air Raids".

This report is commonly known as the Binger Report, having been prepared after a visit to England by Walter D. Binger, Chairman of that committee. I have had access to that report and find that it deals for the most part with the protection and conduct of civilians during and after air raids and deals very briefly with the question of guarding of water works plants. It refers to the fact that certain guards have been stationed in the vicinity of such plants but not primarily for the guarding of such plants against sabotage, although the presence of such troops in particular instances would undoubtedly militate against sabotage.

It appears from the answer from the War Department that we are still left to our own resources with such advice as may be obtained from State, military, police, utility and health authorities.

The general meeting was held in the ballroom of the hotel. Chairman, Erville R. Coffey, M.D., Assistant Surgeon General, United States Public Health Service.

A paper, "Public Health Liaison in National Defense," was read by Joseph Bolten, M.D., Medical Director, United States Public Health Service, Liaison Officer, First Corps Area.

A talk, "Emergency Medical Care in Civilian Defense," was given by Dudley A. Reekie, M.D., Senior Surgeon, United States Public Health Service, Medical Director N. E. Office for Civilian Defense.

A paper, "Public Water Supply in the Civilian Defense Program," was read by R. E. Tarbett, Senior Sanitary Engineer, United States Public Health Service. Percy A. Shaw, Warren J. Scott, Francis H. Kingsbury, Major Brewster and Howard C. Mandell took part in the discussion.

MAY, 1942, MEETING

MANCHESTER COUNTRY CLUB
Manchester, New Hampshire
Thursday, May 21, 1942

Vice-President Horace L. Clark in the chair.

The Association was welcomed to Manchester by Mayor Wilfred A. Laflamme.

A paper, "Cleaning, Sterilizing and Incorporating the Amoskeag Mills Water System into the Manchester, N. H., City System," was read by Percy A. Shaw, Superintendent and Engineer, Manchester Water Works, Manchester, N. H. William B. Duffy, Earle A. Tarr, Percy R. Sanders, Roger W. Esty, and Theodore Cate took part in the discussion.

OBITUARY

George Field Merrill

George Field Merrill, 67, Superintendent of the Ware Water Department since 1924, died suddenly on December 29, 1941, following a heart attack. He was attending the weekly luncheon of the Ware Rotary Club when he was stricken.

Mr. Merrill was born in Shelburne Falls on September 9, 1874, the son of George C. and Anna (Field) Merrill. He attended Arms Academy and studied engineering in the office of Clapp and Abercrombie in Greenfield. He worked as a civil engineer for the Boston and Albany, Rutland and Canadian railroads and later served as engineer and superintendent on federal projects in San Antonio, Texas and Forts Dade and DeSoto in Florida.

In 1896, Mr. Merrill was engaged in the location and construction of about seven miles of street railway as rodman at Shelburne Falls, Mass. From 1897 to 1899 he was in the employ of the Boston and Albany Railroad as instrument man and masonry inspector in connection with the abolition of grade crossings, also in building construction. During 1900 he was employed for about six months as instrument man on the construction of the Rutland Canadian railroad. From 1900 to 1904 he engaged in the location and construction of about nine miles of the Greenfield, Deerfield, and Northampton Street Railroad, including the field engineering and foundation work for a steel bridge 375 feet in length with concrete-filled steel piers. During this period, he was employed by the Clapp and Abercrombie Co., Civil Engineers. In 1904 and 1905, Mr. Merrill engaged in the construction of barracks and quarters at the cavalry and artillery addition also of roads, water works, and sewers at Fort Sam Houston, Texas, as Assistant Superintendent of Construction, Quartermaster's Department, at large under Captain L. J. Fleming, Constructing Quartermaster.

From 1905 to 1907, Mr. Merrill was in charge of the construction of quarters, ordnance storehouses, paved brick roads and walks, the making of repairs to a dock, and the erection of a building for a

pumping station and ice-plant while stationed at Forts Dade and DeSoto, Fla. as Civil Engineer and Superintendent of Construction under the Constructing Quartermasters. Both of these positions were obtained by Civil Service appointment after examinations. From 1907 to 1917 he engaged in the construction and maintenance of water works as Civil Engineer and Superintendent at Greenfield, Mass. This work included the building of an additional supply consisting of a concrete dam, a large open well of reinforced concrete sunk by the open caisson method, an open filter bed, pumping station with a capacity of 3 m.g.d., electric pump and other mechanical equipment, and the laying of about 4000 feet of cast-iron pipe 16 and 18 inches in diameter. This work was built by the Department on force account, and included the construction of an equalizing reservoir of concrete with groined arch roof of 2½ m.g. capacity and the laying of about one mile of 24-in. cast-iron pipe.

On August 4, 1923, Mr. Merrill resigned and was succeeded by H. L. Field. Mr. Merrill came to Ware as Superintendent of the Water Department in 1924 and held this position until his death. Major extensions to the system were made by him, including the installation of hydrants in the business and residential sections. Many miles of old mains were cleaned, and new equipment was installed at the pumping station.

"George" as he was known to all was an active member of the New England Water Works Association and contributed to discussions and acted on various committees. His whole life, his every waking moment were given over to engineering, and his advice and counsel were sought by many who knew him.

In Ware, Mr. Merrill was a vestryman of Trinity Episcopal Church, a member of Eden Lodge of Masons, and Ware Rotary Club. He was a member of the American Society of Civil Engineers, and a charter member of the Greenfield Lodge of Elks. Mr. Merrill spent three days without rest during the hurricane and flood of 1938. He was instrumental in providing temporary water connections on the south side of the Ware River when that section of the town was cut off from the main area as the bridge collapsed, and he took a prominent part in rescue and relief work in the floods of 1936 and 1938.

Besides his widow, Mr. Merrill leaves four sons, Eustace I. of Plainfield, N. J., Lloyd and Neale of Ware, and Douglas K. of South-

bridge; a sister, Mrs. Herbert P. Ware of Shelburne Falls; three brothers, Phillip and Roy of Shelburne Falls and Edward of West Roxbury; and two grandchildren.

JAMES W. REILLY

ALEXANDER H. O'BRIEN

Alexander H. O'Brien, Registrar of the Holyoke Water Department, died in his home, 8 Beacon Avenue, Holyoke, Mass., on January 11, 1942. Although in failing health for many years, the end came suddenly and was a great shock to his associates and to many friends.

Mr. O'Brien was born in Holyoke, April 9, 1876, the son of John T. and Mary (Welch) O'Brien and was educated in the Holyoke schools. He entered the employ of the Water Department as Clerk in the Office of the Superintendent in 1903, became Assistant Superintendent in 1913, and was appointed Registrar in 1920. Previous to his connection with the Water Department, he served on the Board of Aldermen for one year.

Possessed of a beautiful baritone voice which was generously used for entertainment of social gatherings, he was, in his younger days, a member of the St. Jerome Choir and later the Choir of the Holy Cross Church.

He was one of Holyoke's leading golfers, and when in form played consistently in the low seventies. He was also a well known whist player, taking part in several tournaments with better than average success.

Besides his affiliation with the New England Water Works Association, of which he became a member January 12, 1921, he was also a member of the Holyoke County Club, Park Lyceum, New England Order of Protection, Holy Name Society of Holy Cross Parish, Holyoke Lodge of Elks, Shields Court M. C. O. F., and the Royal Arcanum.

He left, besides his wife Margaret (Healy) O'Brien, three sons, John T., A. Edward, and Ralph E. O'Brien, all of Holyoke; two daughters, Mrs. James E. Kenney of Holyoke and Mrs. Austin Gilfoil of Northampton, and four grandchildren.

In his death, the City of Holyoke lost an able and efficient public servant and his departure is mourned by his associates and friends.

PATRICK J. LUCEY
HUGH MCLEAN

ABEL REYNOLDS

Memoirs often are only a listing of the pertinent facts of a life and a career ended. If, somehow, there could be woven into the drab fabric some threads of the personality of the departed, the record thus might be made more truly representative and satisfying. These are things we feel, however; they are not easily uttered, either verbally or in writing. We do not know how to put adequately into words the sudden, depressing realization that one, such as Abel Reynolds, with whom we liked to associate, will not again meet with us in the familiar places.

His career was in the best American tradition. Conspicuous diligence and inherent ability, supplemented by a rare combination of keen business insight and genial disposition, brought him continual advancement. Moreover, he took time, throughout his busy life, to contribute importantly to numerous activities in his community. Church, fraternal, and other organizations asked and received his assistance.

Mr. Reynolds was born in Providence, May 5, 1872, and spent his entire life in that city. He obtained his education in the public schools, the famous private school of Mowry and Goff (afterward the University Grammar School), and the Bryant & Stratton Business College.

Abel began work as timekeeper with the Armington & Sims Company, builders of the well known steam engine of that name, finally becoming head accountant before the concern discontinued operations. In 1899, at the age of 27, he became a meter reader with the Narragansett Electric Lighting Company. At this time, the company's customers numbered 1600; on the 25th anniversary of his employment, the total had increased to 50,000. In the early days, many humble tasks were assigned to him, and so faithfully did he

perform them that gradually he was given assignments of much greater importance. He became successively, secretary to the general superintendent, Walter L. Barnes; secretary to Marsden J. Perry, President; and engineer assistant to Arthur B. Lisle, General Manager. When the company was taken over in 1927 by the New England Power Association, he was made manager of the Warren and Bristol Division.

Mr. Reynolds left the Narragansett Company in 1928 to become associated with Mr. Lisle in the management of utilities. Among the offices he held were general manager and treasurer of the New England Water, Light, and Power Co.; president of the Wakefield Water Co.; vice president of the East Greenwich Water Co.; vice president of the Pawtuxet Valley Water Co.; vice president of the Warren & Coventry Water Co.; president of the Cottage City Water Co.; and vice president of the Exeter, N. H., Water Co.

In civic life, Mr. Reynolds served for 14 years on the Providence School Committee, exerting a powerful influence in the deliberations and decisions of this important organization. He was chairman of various sub-committees, including that on schoolhouses. He was a member of the Olneyville Business Men's Association, chairman of the Board of the Free Public Library of that community, and for the last ten years president of the Trustees.

In Providence Mr. Reynolds was a member of the Turks Head Club and the Providence Engineering Society. In the Masonic fraternity he held membership in numerous bodies: Past Master of Nestell Lodge; charter member of Roosevelt Lodge, treasurer for 17 years; and for a long time secretary and treasurer of the Past Masters Association and of the Masonic Veteran's Association.

After a severe illness of two months, Mr. Reynolds died on February 12, 1942, in his 70th year. Surviving are his wife, Louisa A. Reynolds, and daughters, Mrs. Helen A. Murray and Mrs. Louise D. Bradner. The Church of the Messiah, Olneyville, R. I., was filled with his friends at the funeral services, February 14, 1942.

Many letters from writers in many states have been received by Mrs. Reynolds, expressing not only sympathy, but high regard for her husband and the loss to the water works fraternity. As one wrote, "He always had something constructive to contribute". Perhaps the

best commentary of all, needing no elaboration, is the long enumeration in the preceding paragraphs of the positions of trust he held and filled with rare ability.

Abel Reynolds was elected our treasurer in September 1938, and served with fidelity. Not only will he be greatly missed in this capacity, but at our meetings and conventions where many eagerly sought his sound advice and lively companionship.

CHARLES G. RICHARDSON
EDWIN H. ARNOLD

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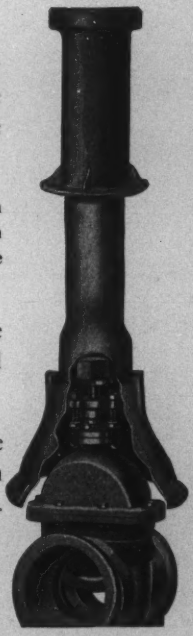

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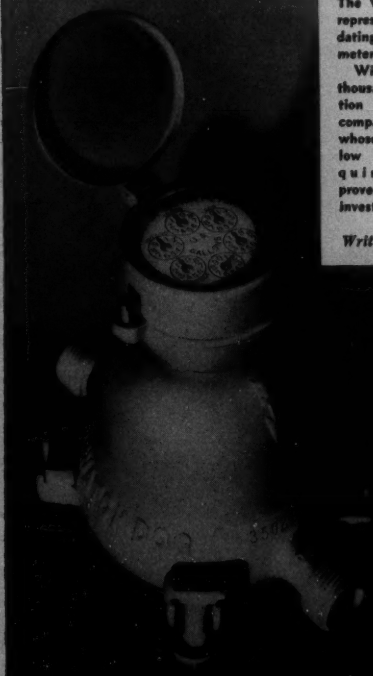

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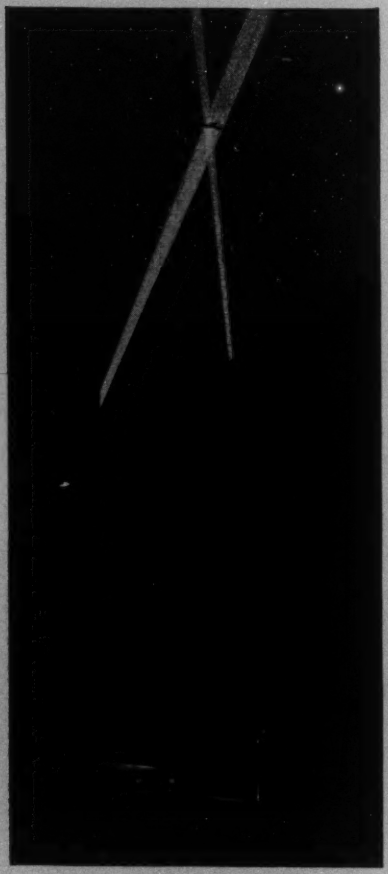

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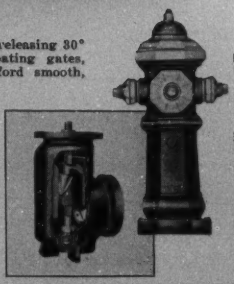

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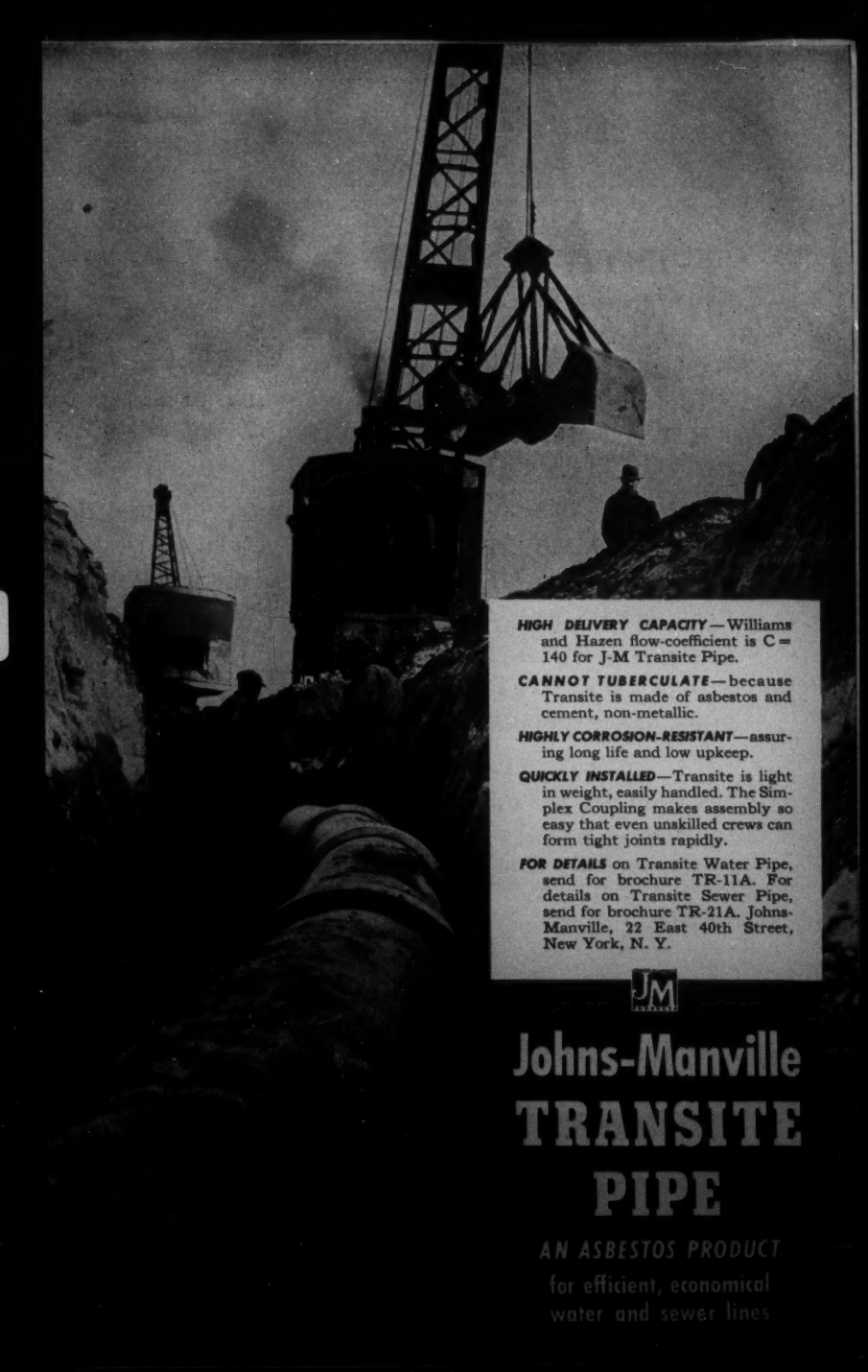

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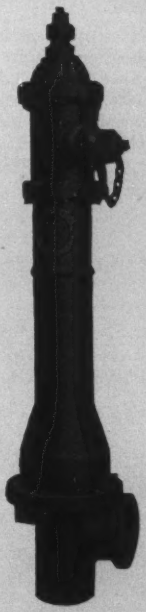

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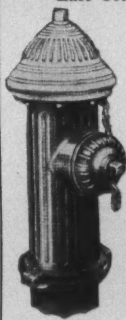

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We also make a new type of hydrant which has a breakable joint at the ground line which when struck with an impediment will break at a specified point and only a coupling has to be used to repair the hydrant, which will be back in service in twenty (20) minutes.
"HYDRANT WITH BREAKABLE COUPLING"

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WATER WORKS SPECIALTIES & SUPPLIES
THE A.P.SMITH MFG.CO. *East Orange.N.J*

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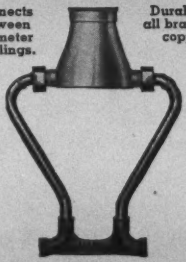
AN IDEAL FITTING *for* RAISING TOO-LOW METERS EASILY

Connects between old meter couplings.

Durable,—all brass and copper.



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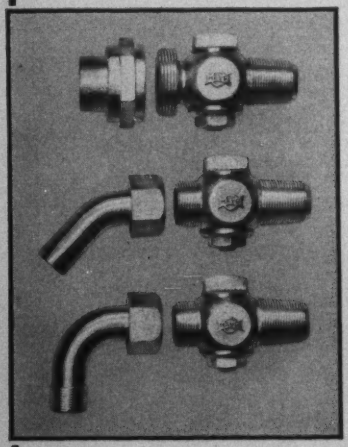

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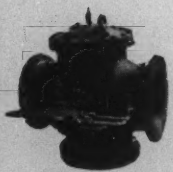

Controls elevation of water in tanks, basins and reservoirs

ALTITUDE VALVE

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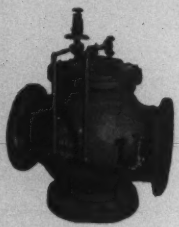
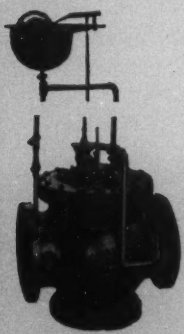
2. Double Acting



Maintains desired discharge pressure regardless of change in rate of flow

REDUCING VALVE

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.



Maintains levels in tank, reservoir or basin

1. As direct acting

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

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A self contained unit, with three or more automatic controls

COMBINATION VALVE

Combination automatic control both directions through the valve.

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SURGE-RELIEF VALVE

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RED HED CORPORATIONS

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Manufacturers of

RED HED Brass Goods for Water Works

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ESTABLISHED IN 1803

Made by R.D. WOOD Company

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Relocated 36-inch cast iron pipe at Reading, Pa.

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Pipe bearing this mark is cast iron pipe.

TRADE MARK REG.

Available in diameters from 1¼ to 84 inches.

Cast Iron Pipe Research Association, Thomas F. Wolfe, Research Engineer, 1015 Peoples Gas Building, Chicago, Illinois

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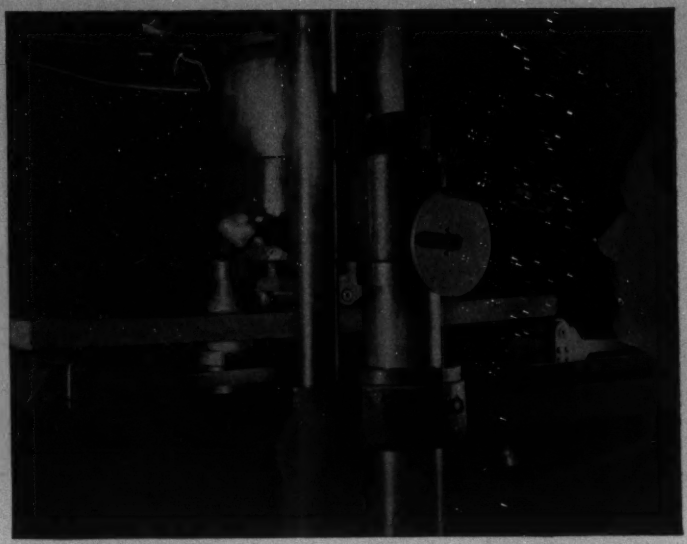

*The "2-inch by 1-inch Test Bar Test," illustrated above, is an acceptance test for cast iron pipe. The breaking load and deflection of the bar, which indicate the physical characteristics of the metal, are determined from this test. It is one of the routine tests made by this Company to insure that the quality of its pipe meets or exceeds the requirements of accepted standard specifications for cast iron pipe. *United States Pipe and Foundry Co., General Offices, Burlington, New Jersey.* Sales Offices in Principal Cities.

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cast iron
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Centrifugally or Pit Cast for water, gas, sewerage, drainage and industrial services

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is a quarterly publication, containing the papers read at the meetings, together with reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness.

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